FERTILIZERS

BY

E. B. VOORHEES

REVISED by JOHN H. VOORHEES

The Rural Science Series

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FERTILIZERS

THE SOURCE, CHARACTER AND COMPOSITION OF NATURAL, HOME-MADE AND MANUFACTURED FERTILIZERS, AND SUGGESTIONS AS TO THEIR USE FOR DIFFERENT CROPS AND CONDITIONS

BY THE LATE

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FERTILIZERS

CHAPTER I

NATURAL FERTILITY OF THE SOIL, AND SOURCES OF LOSS OF THE ELEMENTS OF FERTILITY

There is no one question of greater importance to the farming industry than that of soil fertility. In order that the industry may be successful, it is not enough to produce crops; it is necessary that their production shall result in a genuine profit. That is, it is not enough to produce crops which bring more than they cost in the way of labor and manures, without taking into consideration the effect of their growth upon the future productive capacity of the soil. The relation of the outgo and income of the fertility elements is an important factor in determining profits, and must be considered. The farmer who secures crops that bring more than they cost, and who, at the same time, maintains or even increases the productive capacity of his soil, is, other things being equal, the broadly successful farmer. Many farmers are able to accomplish this object because of the knowledge they have acquired through long years of experience, rather than because they possessed in the beginning of their work a definite knowledge of the fundamental principles involved in crop production, and

upon the observance of which their success depended. One of the first needs, therefore, in the use of commercial fertilizers is a more or less definite knowledge of what constitutes fertility, and of the principles which underlie crop production.

SOIL FERTILITY

The full meaning of the term "soil fertility" is not easily expressed, since many conditions are involved, all of which exert more or less influence. The potential fertility, which is measured by the total content of the food elements contained in a soil, is made practicable, or usable, in proportion as the conditions are favorable. The more important of these influencing conditions are here briefly discussed. In the first place, it is of the utmost importance that a soil should contain those elements found in the plant; hence, it is almost self-evident that a fertile soil must contain a maximum quantity of those particular elements or constituents which are removed from the land in maximum amounts by the crops grown. The removal of crops rapidly exhausts the soil of these elements, and finally reduces the quantity contained in the soil to so low a point as to make profitable cropping impossible.

Chemical elements needed in plant growth.

Careful studies and experiments have shown that plants actually take from the soil at least ten chemical elements which are required for their normal growth and development: viz., nitrogen, potassium, phosphorus, magnesium, sulfur, sodium, iron, chlorin, silicon and calcium. Besides these elements, others are often found, including manganese. It is not to be inferred that all

of these elements are required by all plants. There are many plants which grow to maturity without sodium, silicon and chlorin, but all of the others must be present for normal growth. Carbon, hydrogen and oxygen are also found in plants, but these elements are secured from air and moisture.

The number of soil constituents liable to rapid exhaustion is limited in many cases to three, and at most to four, which are nitrogen, phosphoric acid (phosphorus), potash (potassium), and lime (calcium), the latter only in exceptional cases. These are liable to be exhausted because they exist in larger amounts than the others in the plants that are grown, and in smaller amounts than the others in even the most fertile soils. It has also been proved that it is the one element of these which exists in the smallest amount which measures the crop-producing power, or fertility, in this respect, as one element cannot substitute or exert the full functions of another. That is, there may be a relative abundance in the soil of potash and of phosphoric acid, but practically no nitrogen, in which case good crops of cereals, for instance, could not be grown, because no other element can substitute the nitrogen required by the plant, and it can be obtained by it from no other source than the soil; and the soil, for all practical purposes, is quite as unproductive, lacking in productive fertility, as it would be if it contained much smaller amounts of the mineral elements mentioned, and thus be poorer in potential fertility.

Fertility as influenced by water, climate and season.

In the second place, there are soils that are so rich in all of these elements that if productiveness depended upon them alone, maximum crops might be grown for

centuries without exhausting them, while actually they are now incapable of producing a single profitable crop of cereals, grasses, fruits or other products of the farm, because certain other conditions which are essential, in order to bring them into activity, are absent. For example, it may be that water, which is absolutely essential both for the solution of these food elements in the soil, as well as for their distribution in the plant after they have been acquired, cannot be obtained, or that the temperature of the soil and of the surrounding air is either too low or too high, thus preventing or interrupting the progress of those changes which must go on, both in the soil and in the plant, in order that normal growth and development may be accomplished. With a full supply of the fertility elements in the soil, the climatic and seasonal conditions exert an important influence upon its productive power.

It is evident, therefore, that the chemical elements of fertility in themselves are not sufficient to constitute what we understand by the term. Fertility is not measured by them alone; associated with them there must be other conditions. That is, while crops cannot be grown without these elements, it is the conditions which surround them that, in a large degree, determine the power of the crop to secure them.

The influence of physical character of soil.

In the third place, the physical character of a soil is also a factor in determining actual fertility. This has reference, first, to the original character of the rocks from which the soil particles were derived, whether hard and dense in their mineral character, thus resisting the penetration and the solvent effect of air and water and other

agencies, or whether soft and friable, and freely permitting their entrance and action; and secondly, whether, in the formation of the soil, the particles were so fine and so free from vegetable matter as to settle in hard and compact masses, impervious to water, air and warmth; or whether they were coarse, and not capable of close compaction, thus giving rise to an open and friable soil, freely admitting the active natural agencies, such as we find to be the case in sandy soils. In addition to these properties of soils, which have a distinct place in determining fertility, there are many other minor ones which together constitute what is understood as "condition."

Location of soil qualifies the term "fertility."

Furthermore, fertility, even in this true sense, may be useless because of the location of the soil which possesses it. For example, there are many places on this continent where sugar-producing plants will grow and develop perfectly, since the soils are very rich in the fertility elements, and since the surrounding conditions are most favorable for their culture, yet, because of their location, it is unprofitable to grow them for the manufacture of sugar. In the first place, the soils are so situated as to make it impossible, or at least impracticable, to provide the means necessary for converting the sugar-producing crop into actual sugar, and, in the second place, even if it were possible to do so, the great distance from shipping stations to markets so increases the cost of transportation as to make it unprofitable to compete in the market with the crops grown upon lands possessing true fertility in a lower degree.

Practical fertility is usable potential fertility.

Practical fertility, therefore, is dependent upon many conditions, and fortunately our own country possesses it in a marked degree; that is, the utility of the potential fertility, as represented by the total mineral content of our soil, is such as to make us one of the greatest agricultural nations in the world, both in the quantity and variety of products grown. Our soils possess the essential elements in lavish amounts, and our climatic and seasonal conditions are such as to permit of their ready conversion into a wide series of valuable products, and our location and facilities for handling and distributing our staple crops are such as to enable us to compete in any market of similar commodities.

Notwithstanding the truth of this general statement, it is also true that in certain sections of our country profitable crops cannot be grown without the addition of commercial fertilizers, because the soils are either naturally poor, or they have become partially exhausted of their plant-food elements. That is, the amounts that become available to the plant through the growing season are not sufficient to enable the plant to reach a maximum development, though other conditions are perfect.

Our future progress depends, therefore, upon how well we understand and apply the principles which are involved, both in the conservation and use of the fertility stored up in our soils, and in the use of purchased fertility; and in this connection it is important to consider the sources of loss of the essential fertility elements, or those which in the beginning measured our capabilities in crop production.

WHAT BECOMES OF OUR FERTILITY?

Since fertility is dependent upon so many conditions, or, in other words, since the essential elements of fertility are dependent upon their utility, and since, in this sense, fertility is largely determined by natural conditions, it is pertinent to inquire, first, whether under our present systems of management, or mismanagement, of the land, it is suffering any natural loss of fertility. As already pointed out, the most important function of fertility is to furnish nitrogen, phosphoric acid and potash, and since the content of these in our soil, together with the knowledge we have as to their use, measures, in a sense, our prosperity as an agricultural people, the possibilities of losing them from the soil is a matter of national concern, and is of vital interest to individual farmers, who, in the aggregate, make up that part of the nation directly affected by the results of such loss.

It would, perhaps, be possible, by a careful chemical survey of our soils, to determine both the actual and potential fertility of our entire country, and this knowledge, together with an accurate measure of the intelligence exercised in its use, would enable a prediction as to our future development, if present methods were continued. That is, whether our land would become barren and worthless, as has been the case in many older countries which at one time were quite as productive, or whether it would constantly increase in productiveness, even with continuous and profitable cropping,—although, as already pointed out, the present barrenness or sterility of a country formerly fertile may not be due entirely either to the natural or to the artificial loss of these constituents.

SOURCES OF NATURAL LOSS OF NITROGEN

Of the essential constituent elements, nitrogen is, in one sense, of the greatest importance; first, because it is the one that is more liable to escape than the others, and secondly, because it is more expensive to supply artificially than are the minerals. It is the most elusive of all the elements: to-day it may be applied to the soil, to-morrow it may be carried in streams to the ocean. It is also unstable — which is not the least valuable of its characteristics if properly understood: to-day it is an element of the atmosphere, to-morrow it is a constituent part of a growing plant, the next day the same element may exist as an animal product, and the day following it may be returned to the soil to feed the plant. It is more liable to escape than any of the others, because it is available as plant-food largely in proportion as it changes to a nitrate, and after it assumes that form it is seldom absorbed or fixed in the soil. Nitrogen in this form remains freely movable, and the probability of loss by leaching is increased in direct proportion to the lack of preventive measures used, or the presence of those conditions which favor leaching. The latter may be classified as follows: First, the amount and time of the rainfall; secondly, the absorptive and retentive power of the soil and subsoil, due to their mineral and physical character; and thirdly, the amount of vegetable matter (humus) acquired by the soil, which retards the passage of water. While the amount and time of rainfall cannot be controlled, its effect upon our soils in this direction can be largely governed if proper attention is given to correcting the other conditions, and these may be largely modified, if not entirely controlled. In the matter of the

absorptive and retentive power of soils, it has been shown that if they are well supplied with vegetable matter and carefully cultivated, they retain and hold the plant-food constituents in a much greater degree than if devoid of humus and improperly managed, and also that the drainage water from soils upon which crops are growing seldom contains more than the merest trace of nitrates. The loss of nitrogen through the operation of the forces of nature may, therefore, be reduced by the careful management of the soil.

Importance of careful culture.

The presence of suitable amounts of vegetable matter, and good cultivation, are conditions that are within the power of all farmers to provide, though it is sometimes impracticable to keep the land continuously covered with a crop; and sometimes it is thought that the loss incurred through leaching because of the absence of a growing crop is more than balanced by the gain in other directions. For example, though losses of nitrates may occur, the gain in availability of the mineral constituents, phosphoric acid and potash, with the accompanying improvement in texture, due to the exposure of the soil to atmospheric influence, more than balances these losses, particularly during the winter, with its wide changes of temperature.

Loss of nitrogen by drainage.

It has been shown by carefully conducted experiments, both in this and other countries, that in a season of average rainfall the drainage waters carry away from one acre, from uncropped soils only fairly rich in plant-food, as much as 37 pounds of nitrogen a year, while when continually cropped the drainage waters from the

same soils contain practically no nitrogen. This difference in the loss of nitrogen under the two conditions may not seem a great matter at the first glance, but a careful study of the bearing of this loss in its relation to crop production shows that it is really a serious matter. In the first place, the amount of possible loss annually is practically equivalent in nitrogen to the amount contained in two tons of timothy hay, or in one ton of either wheat, rye, oats, corn or buckwheat, quantities nearly double the average yield to an acre of these crops throughout our whole country; and in the second place, that the nitrogen which is carried away by the drainage water is in the very best form for feeding the plant, or it would not have been lost, and thus its loss leaves the soil not only poorer in this constituent element, but poorer in the sense that the remainder of it in the soil is in a less useful form. Furthermore, if this nitrogen is to be returned to the soil in the same form, which is the cheapest, it would cost at present prices $6.85.

Escape of nitrogen into the atmosphere.

Another source of natural loss of nitrogen is its escape from the soil as gas into the atmosphere. This is due to the oxidation of the vegetable matter, or to "denitrification," which takes place very rapidly when soils rich in vegetable matter are improperly managed. The possibilities of loss in this direction are strongly shown by investigations carried out at the Minnesota Experiment Station on "the loss of nitrogen by continuous wheat raising." The results of these studies show that the total natural loss of nitrogen annually was far greater than the loss due to the cropping. In other words, by the system of continuous cropping, which is universally observed in

the great wheat fields in the Northwest, there were but 24.5 pounds of nitrogen removed in the crop harvested, while the total loss to the acre was 171 pounds, or an excess of 146 pounds, a large part of which loss was certainly due to the rapid using up of the vegetable matter by this improvident method of practice. Whereas, on the other hand, when wheat was grown in a rotation with clover, the gain in soil nitrogen far exceeded that lost or carried away by the crop. The continuous wheat- and corn-growing in the West, and of cotton and tobacco in the southern states, are responsible for untold losses in this expensive element of fertility, while in nearly every state of the Union, soils both rich and poor are suffering more or less from the effect of natural losses in this direction.

THE NATURAL LOSS OF THE MINERAL ELEMENTS

In the case of the minerals, phosphoric acid and potash, which exist in fixed compounds in the soil, the actual losses are undoubtedly very much less than is the case with nitrogen, since only traces of these constituents are ever found in solution in the drainage waters under ordinary circumstances; yet, because of the large quantity of water that passes through many of our soils, the total amount of these rendered soluble and carried away by this means is very great. Our great rivers carry in solution into the ocean tons upon tons annually of these elements of fertility, and it is an absolute loss, as there is no natural means by which these may be returned to the soil, as is the case with nitrogen; and it is true, as in the case of the former, that the soil is not only absolutely poorer by virtue of the loss of its elements of fertility,

but poorer in the sense that the immediate utility of those remaining is reduced. These silent and unseen forces constantly at work are reducing the content of these constituents in our soils to an alarming degree, and it is because they are unrecognized forces that the disastrous results of their activity are not fully appreciated, and, consequently, the best means for restoring them are not used.

Losses due to mechanical means.

A serious loss of all the fertility elements is also due to mechanical means. Aside from the amounts that the rivers of water are carrying in solution into the seas, immense amounts are carried in them in suspension. The results of this kind of loss are painfully evident; in many of the southern states, and in sections where the forests have been removed and the land abandoned, the soils have been washed and gullied until not only the very best portions, but in some cases the largest portions, have been carried away.

It is not, however, in the abandoned parts of the country alone that these mechanical losses of constituents are of importance — they are more or less apparent on every farm, and are measured by the methods of management. Soils that are allowed to lie bare and fully exposed to the storms of wind and rain throughout the larger part of the year suffer the greatest loss, while from those which, on the other hand, have crops growing during a large part of the year, and which hold the soil particles together and prevent their easy movement, the losses are reduced in both the directions mentioned. The beneficial results derived from the use of good methods are cumulative; the benefit is not only immediate, but continuous.

ARTIFICIAL LOSSES OF FERTILITY

In addition to these natural losses of fertility, there are the artificial losses of the constituents, or those due to the removal of crops. These, of course, necessarily accompany all farming operations, and, provided that in the removal and sale of the constituents in the form of crops, the farmer has received a fair price for them, they are entirely legitimate.

The sale of farm products is really in the last analysis a sale of actual constituents, together with a certain portion of the "condition" of the land, which is not readily measurable. That is, it is the constituents in the soil, together with the conditions surrounding it, that the farmer buys when he buys land. If an acre of land, containing within the reach of the roots of the plant, say, 3000 pounds of nitrogen, 5000 pounds of phosphoric acid and 6000 pounds of potash, sells for $100, the seller receives the $100, not for so much dirt, but really for the constituents contained in it. The purchaser believes that, with the conditions surrounding them, he can convert them into products which he can sell and from which realize a profit. If in selling these amounts of the constituents in the form of land, a lower price to the acre is received, it is because the natural conditions which surround them, and which influence their utility, are less favorable, and a greater proportionate effort and expense are necessary to secure them in the form of salable products. The difference in the price of land is not always due to the content of the constituents, but often to the conditions surrounding them. In many cases, the soil may serve simply as a medium in which plants can grow, and the content of the fertility elements is of minor im-

portance. Such would be the case in the growing of market-garden crops near large cities, the location near the consumer being of greater importance, in the case of perishable crops of this sort, than the chemical character of the soil. In the larger number of cases, however, the natural fertility fairly measures the market price. At the price to the acre, and for the quantity of constituents here assumed, the buyer would pay at the rate of 1½ cents a pound for the nitrogen, and ½ cent a pound each for the phosphoric acid and potash, and it now constitutes his capital stock.

A comparison of the prices received for the fertility elements in different crops.

A comparison of the prices paid for the constituents in land, with the prices received for the same constituents when contained in the different crops (disregarding for the moment the value of the "condition" of soil), will make clearer this matter of rational sale of constituents, which represents a reduction of our capital stock of fertility. For example, if wheat is raised which contains 1.89 per cent of nitrogen, .93 per cent of phosphoric acid and .64 per cent of potash — or in round numbers, 38 pounds of nitrogen, 19 of phosphoric acid and 13 of potash to a ton — and is sold for 80 cents a bushel, or $26.65 a ton, the nitrogen sells in this form for 55 cents a pound, and the phosphoric acid and potash for 18 cents each a pound. That is, the 80 cents a bushel, or the 55 cents a pound, received for the nitrogen, and 18 cents for the potash and phosphoric acid, represent what has been received for a pound for the capital stock of these elements, which at $100 an acre were purchased at the prices previously mentioned; 1½ cents a pound for the nitrogen

and ½ cent a pound for the phosphoric acid and potash. The labor in raising the crop, the expense of harvesting and putting it upon the market, and the profit, must come out of the difference between what is paid and what is received. Naturally, as the ratio between the constituents contained in the products sold and the price received is increased, the rate of income to a unit of exhaustion is increased, though in many cases the increased cost of the labor necessary is in proportion to the increased price received. This may be illustrated by a comparison on the fertility basis of the sale of wheat and milk. If milk, which contains on the average 12 pounds of nitrogen, 4½ pounds of phosphoric acid and 3½ pounds of potash to a ton, is sold for $1.50 a hundred pounds, the nitrogen is sold for $2 a pound, and the phosphoric acid and potash for, approximately, 70 cents a pound. In the sale of milk at this price, the rate of income to a unit of exhaustion is increased nearly four times over that of the wheat, though, because it is in one sense a manufactured product, the cost of labor to a unit of plant-food contained is largely increased. Again, if cream is sold, the prices received for the constituents are still further increased, while if the milk is made into butter, and that alone is sold, the prices received measure the expenses and profit, and the capital stock of fertility is not materially reduced, though it is in another form and in another place.

Fertility content of cereals and vegetables.

The losses of the constituents in the sale of cereals and grasses, corn, oats, wheat and hay are, too, relatively greater than in the sale of vegetables and fruits, as lettuce, celery, potatoes, tomatoes, sugar-beets, apples, berries and kindred crops, though in the case of the latter,

a higher degree of fertility is necessary in order to produce maximum crops, and the cost of production is again proportionately greater. These facts strongly emphasize the necessity of a careful study of the relation of farm practice to the artificial losses of fertility.

The artificial loss of fertility that may be incurred by the sale of crops is largely measured by the knowledge of the producer concerning the relation between the price received for the crop and the fertility contained in it, and thus removed when sold, and by his intelligence in adjusting his methods so as to reduce to a minimum the actual loss.

The following tabular statement shows very clearly the differences in the losses of the constituents in the sale of different classes of plants:

FERTILIZER CONSTITUENTS IN CEREALS AND VEGETABLES

	Pounds in One Ton		
	Nitrogen	Phosphoric Acid	Potash
Cereals and Grasses			
Corn	29.6	12.2	7.2
Oats	36.2	15.4	11.4
Wheat	34.6	19.2	7.0
Rye	32.4	16.2	10.4
Timothy hay	21.6	7.0	26.8
Herd grass	20.0	7.0	31.4
Vegetables			
Carrots	3.2	1.8	9.2
Parsnips	4.4	3.8	12.4
Potatoes	5.8	1.6	10.2
Radishes	1.6	1.0	8.0
Beets (red)	4.8	1.8	8.8
Lettuce	5.0	1.6	9.0
Celery	5.0	4.0	15.0

Irrational farm practice.

There are methods of practice which are entirely irrational, and contribute to the real losses of fertility. Farming is unprofitable, not altogether because the land is exhausted, but because only those crops are grown which possess a high fertility value, and which have a low market price, and thus the prices received for the constituents in the crop are actually less than they cost in land and in labor; and these methods of practice are not confined to farmers whose lands of inexhaustible fertility have been given them by a generous government, but are followed by farmers who annually purchase commercial fertilizers to supply the losses of fertility thus sustained.

Where the conditions are such as to make it impracticable to grow and sell crops, as such, of a low fertility value, the producer should endeavor to sell the manufactured rather than raw materials, — that is, to so use his crude products as to lower the quantity of the constituents contained in those sold, which explains, in part, the greater success in the long run of a mixed husbandry, rather than single-crop farming.

The artificial losses of our national capital stock of fertility are, however, not absolute, if the products are consumed in our own country, as more or less of the constituents contained in the crude products sold find their way back to the farm, either in the by-products of the mills, in sewage, in the manure from cities, or in various vegetable or animal wastes; but when they are exported, the loss is absolute, and the amounts so disposed of are in some degree a measure of the rate of loss of the capital stock of fertility in our lands, though to these must be added the losses due to the improper use of manure and other waste materials.

Losses in manures.

It is natural to infer that proper losses of fertility are confined to the removal of the constituents in the sale of farm products, and that those contained in the materials not sold and in the feeds used upon the farm are again returned in part to the land. Theoretically this is correct, but the losses that do occur, particularly in the handling of manures, should not be overlooked. While it is impossible to even roughly estimate the waste or loss of fertility due to the improper making or handling of manures, some idea may be obtained when the enormous amounts produced and the sources of possible loss are considered.

If this enormous mass of waste material were properly used, it would go a great way toward increasing the present and immediate fertility of our soils, or in retarding the time of exhaustion, and it is quite pertinent to inquire if it is properly used. It has been demonstrated by experiments at Cornell Experiment Station that 50 per cent of the total constituents in farm manures is liable to be lost by ill-regulated fermentation and by leaching; and further, careful observations and experiments show that the conditions in the larger number of barnyards are such as to encourage the maximum loss by these means. It is morally certain that a large percentage of the constituents contained in them are lost; they never reach the right place on the farm.

It is estimated that if but one-tenth of the present waste could be avoided, — and a very large part of it is practically avoidable, and at a very slight expense, — the total amount of constituents that may thus be saved for further use would be more than equivalent to the amounts now

purchased in the form of commercial fertilizers. This estimate is certainly conservative, and clearly demonstrates the serious drain upon our resources of fertility elements, due to the lack of care in the handling of farm manures.

The conditions, as here pointed out, not only suggest the need of imported plant-food, but that there are opportunities for reducing this need by careful saving and use of the constituents that are subject to waste.

CHAPTER II

THE FUNCTION OF MANURES AND FERTILIZERS, AND THE NEED OF ARTIFICIAL FERTILIZERS

WHILE in a broad sense a manure or fertilizer may be regarded as anything that will increase the yield of a crop if added to the land, the chief function of manures is to furnish nitrogen, phosphoric acid and potash.

THE ESSENTIAL ELEMENTS OF FERTILIZERS

These are called the "essential manurial elements," or "constituents," to distinguish them from the others that are needed by plants, because these three are contained in the crops removed in greater amounts than the others, and because they exist in the soil in much smaller amounts than the others. For example, cultivable soils seldom contain too little iron or sulfur, or magnesium. These elements usually exist in quantities more than sufficient to supply all the needs of the plant for them, and, because they are required in such exceedingly small amounts, the soils are seldom exhausted of them. In addition to this property of supplying essential manurial constituents, many substances useful as manures possess, however, a secondary function: they serve to indirectly increase the crop, but do not add directly to the potential fertility of soils.

NATURAL MANURES AND ARTIFICIAL FERTILIZERS

Farmyard manure, and many other natural products, possess this second function in a marked degree, and the indirect manurial value of these is due largely to the good effect that the substances associated with the nitrogen, phosphoric acid and potash in them exert in increasing the crop. This good effect is observed in two directions. First, the vegetable matter contained in the natural manure improves the physical character of soils — those that are clayey and compact, by making them more open and porous, separating the particles, so that the water and air can penetrate more freely, and thus act directly upon the dormant or insoluble constituents that are contained in it; and those that are light and sandy, by filling up the open spaces, thus making them more compact. In the second place, the addition of vegetable matter to soils, even though it contains no essential constituents, improves it by enabling it to more readily and completely absorb and retain not only the water, but also the soluble essential constituents that may be added. The chief distinction between what are known as manures and what are known as fertilizers is the difference in respect to this secondary function. The manure possesses the two functions, the one to supply the essential constituents, and the other to assist plant growth by aiding in the improvement of those already contained in the soil, and this latter function it exerts in a marked degree; while the fertilizer, as a rule, possesses but one, namely, that of furnishing plant-food. The indirect effect of the materials associated with the constituents in artificial fertilizers is seldom very useful, and sometimes may be harmful.

DIRECT AND INDIRECT EFFECT OF MANURES

It is obvious, therefore, that any substance which contains nitrogen, phosphoric acid or potash may serve as a direct manure, and any substance which contains no plant-food, but which possesses the power of improving the physical character of soils, may also serve as a manure, though the one effect is quite distinct from the other. The first adds to the soil the essential constituents; the other helps to make the constituents already in the soil serve as food to the plant.

The use of the one will tend to increase both the potential and practical fertility in the soil, while by the use of the other the active fertility is increased as the potential fertility is decreased. That is, when actual plant-food is added in the form of nitrogen, phosphoric acid or potash, and crops are removed, the exhaustion of the soil is in proportion to the amounts of these removed over and above the amounts which have been added. Whereas, in the other case, when no plant-food is added, the exhaustion is measured by the amount of the constituents removed. It is clear, therefore, that the addition of only indirect manures has a tendency to rapidly reduce the fertility of soils of low natural strength, or those that do not possess large stores of food constituents, whereas, on soils that are rich in the fertility elements, the indirect manuring may result in an increased yield for a long period, though ultimately the soil will become exhausted — if not completely, to such a degree as to render further cropping by this method unprofitable.

There are a number of substances which act in both capacities — directly and indirectly — and in order to understand thoroughly the value of such materials they

must be studied from both points of view. Farmyard manure is an example. It contains nitrogen, phosphoric acid and potash, and possesses the power of improving the physical character of soils. Lime, generally considered an indirect manure, may act in the capacity of a direct manure upon soils sufficiently lacking in this element. Other materials which act in both capacities under peculiar conditions are magnesia salts, iron salts, basic-slag, nitrate of soda and the like.

UNAVAILABLE AND AVAILABLE PLANT-FOOD

While, as already stated, any material containing either one or all of the three essential constituents, nitrogen, phosphoric acid or potash, may serve as a direct manure in the sense that it increases the potential fertility of any soil, the value of the addition of such materials will depend not so much on the amount, as upon the power that the plant may possess of acquiring it — and it is here that the difference between manures from natural sources and those from artificial sources is again quite manifest. That is, the fertility constituents in natural manures are in large part combined with others in the form of vegetable matter, and with the exception of potash, they are, when in this form, largely insoluble, and, therefore, cannot be used by the plants until after decay begins. Whereas, in artificial manures, the constituents may be not only soluble, but may be in a form in which the plants can take them up immediately. In the first case, the plant-food is said to be unavailable, and in the second, it is said to be available.

Nitrogen, one of the chief constituents of manures, for example, exists in three distinct forms: (1) the or-

ganic form, in animal or vegetable matter, derived from any form of life, which must first decay before it can serve as plant-food. (2) As the decay goes on ammonia is formed, and then (3) from the ammonia the nitrate is formed, which is the form in which plants take up the largest proportion of their nitrogen. This process is the direct result of bacterial activity and is known as nitrification. Inasmuch as products exist which contain nitrogen in these three distinct forms, it is possible by their use to control largely the feeding of the plant in respect to this element, while in the case of natural manures, the feeding of the plant with nitrogen depends upon conditions which cause its change from the organic into the other forms. As these conditions are variable, the problem of the economical feeding of plants with nitrogen, other things being equal, becomes a more difficult matter with the natural than with the artificial manures.

Phosphoric acid also exists in different forms, the form measuring to a large degree its availability: the organic, in which the availability depends upon the rapidity of decay; and the soluble and immediately available form, — that is, the form that distributes everywhere, and which the plant can absorb immediately it comes in contact with the roots. Commercial products exist which contain the phosphoric acid in these distinct forms. The user is therefore enabled to supply this constituent in such form as may best suit his crop and soil conditions.

In the case of potash, distinct forms, as muriate, sulfate and carbonate, also exist, though in the case of potash, the form in which it is combined exerts less influence upon the availability of the element to the plant than is

the case with nitrogen and phosphoric acid. All of these forms are soluble, and can be readily absorbed.

DANGER OF LOSS FROM THE USE OF SOLUBLE PLANT-FOOD

The fact that the artificial fertilizer-products contain the constituents in such forms and combinations as to enable them to feed the plant immediately, also presents some disadvantages from the standpoint of economical use. This is particularly true in the case of nitrogen, for nitrogen, when applied in the form of nitrate, in which form it is taken up by the plant, does not combine to make insoluble compounds, but remains freely soluble. A great waste, therefore, may ensue from leaching into the lower layers of the soil and beyond the roots of plants, or into the drains, and the plant-food be carried away, unless care is exercised both as to the amount and the method of application. With soluble phosphates, the danger of loss is much less than with nitrogen. If these are applied in too large quantities to meet the needs of the plants, or under improper conditions, their tendency is not to remain soluble, but to revert to their original and insoluble form. The main fact, however, is that in artificial fertilizers we may have the constituents in distinct and separate forms, which permits the feeding of the plant, rather than the feeding of the soil; and this is usually, and must necessarily be, the case when natural manure products serve as the entire source of the added fertility. For example, nitrogen may be supplied in artificial fertilizers in three forms, each form being distinct and separate from the other, and each giving up its nitrogen to the plant at a different time, supplying its needs as required by growth, in which case the danger of loss is small.

THE USEFULNESS OF A FERTILIZER CONSTITUENT DOES NOT DEPEND UPON ITS ORIGINAL SOURCE

It should be remembered, too, that artificial manures or fertilizers supply plant-food just as well as other and more common products. The fact that the food exists in substances other than those which are familiar to the farmer, is no evidence that it may not be quite as good, or even better, than when contained in his home-made products. It is not the outward appearance of a substance, but the kind and form of the elements contained in it, that measures its value as a fertilizer.

For example, the nitrogen that may be applied in the form of a commercial fertilizer exerts no different function in the plant than that which may be acquired from the original soil, or from materials that have recently been obtained from that soil, and again returned as yard manure. The same is true of phosphoric acid and potash. In their concentrated, artificial forms, they serve to feed the plants in exactly the same way, and exert the same function in them, as those contained in the soils themselves, or that may be contained in wood ashes, or materials more familiar, or of more common occurrence. The form in which they exist when applied does not necessarily imply that they are stimulants rather than food, though frequently, because of their form, the plants are able to absorb them more readily, and thus by their rapidly increased growth, encourage a belief that an undue stimulating effect accompanies their use. The famous experiments of Lawes and Gilbert, at Rothamsted, England, teach this one thing very emphatically; viz., the efficiency of chemical fertilizers as compared with yard manures.

USE OF FERTILIZERS

While manures in the ordinary sense, and even materials which are now included under the head of artificial manures, such as ground bone and wood ashes, have been used for a very long time, the use of artificial products in a true sense is of comparatively recent origin. The first use of genuine artificial fertilizers dates from the publication of Baron von Liebig's book, "Organic Chemistry in its Application to Agriculture and Physiology," in 1840; yet for a long time after this date the increase in their use was very gradual. The very excellent, and at that time surprising, results which were obtained from the application of Peruvian guano, one of the first products to receive attention, manifestly increased the interest in the subject also. These good results were observed more particularly on the continent of Europe, where the lands had been under cultivation for a long time. The use in America, previous to 1860, was quite insignificant. Since the work of Liebig, a very great amount of study has been given to the subject, both in reference to the essential character of the various materials, and their influence upon the production of plants. Perhaps no other single subject relating to agricultural science has been studied more fully than the question of the use of artificial manures; and these studies have resulted, not only in the discovery of new materials, but in their better preparation for use as plant-food, which greatly increased their effective use. There is no question connected with agriculture which is of greater direct and practical importance, particularly in those countries which have been depleted of their active fertility by the means mentioned, or in which the conditions are as pre-

viously outlined, than definite knowledge of the true principles which govern in the profitable use of commercial fertilizers. Yet, notwithstanding all the good results thus obtained, and their great practical importance to agriculture, much still remains to be done, particularly in the establishment of fundamental principles.

While it is desirable that in a work of this kind scientific discussions should be avoided as far as possible, and the subject made as plain as is practicable to those using fertilizers, it is necessary to their right use that those who apply them to their land should have a very clear conception of the underlying principles, so far as they are known, in order that they may intelligently increase their production, and thus reap a profit. Definite knowledge is an important factor in determining their profitable use.

THE NEED OF ARTIFICIAL FERTILIZERS

The considerations in the previous chapter explained in part, and in a broad, general way, the necessity for the use of commercial fertilizers. The conditions of farming in this country have greatly changed in the past thirty years, and these changes have, perhaps, a still more important bearing in showing the need of imported fertility than the conditions already discussed. The first direction in which important changes have taken place is in the increased cost of farm labor and in the relatively low prices now received for the staple crops, the cereal grains, cotton and tobacco.

The cost of production to a unit of income is increased.

The cost of labor is increased because proportionately higher wages are now paid, and because the labor

now obtainable is on the whole less efficient, being performed more largely by those untrained for their work, rather than by the owner and his sons; and this increased cost of labor makes the cost of growing the staple crops much greater in proportion to their market value than was formerly the case, though there are, of course, exceptions.

For example, harvest wages throughout the eastern part of the country, at any rate, were in the sixties regulated somewhat by the price of wheat. When wheat was $3 a bushel in the eastern states, the daily wage was $3. Now the daily wage in the east ranges from $2 to $2.50 a day, while the price of wheat does not often exceed $1 a bushel, and the price received is frequently much lower. The wages for other kinds of farm work are proportionately the same in reference to present prices of products. During the past twenty-five years the cost of labor has increased materially and remains constant regardless of the nature of the work, character of farming, crop grown or season. This condition, considered in connection with the important fact that the total cost of crop to the acre is practically the same, whether the yield is high or low, exerts a decided influence in determining profits, particularly on land of medium fertility. The cost of preparing the land for the seed, the cost of seed and the seeding and harvesting are the same for a crop of wheat, whether the yield is 10 or 30 bushels an acre; but this cost will not permit a profit from the 10-bushel yield, because the cost to the bushel is too largely increased. The same considerations hold true for a number of other crops. Small yields of these relatively low-priced crops cannot be profitably produced with the present high price of labor; and it has been shown, furthermore, that land

which is not in a high state of fertility will not produce large yields.

Many soils, especially those in the eastern and southern sections of our country, which were not originally very fertile, and which have been cropped for a long time, show abundant evidence of the need of fertility from sources outside of the farm, in order that maximum crops may be produced. The aim should be, therefore, to make the conditions of soil better, and, if possible, so perfect as to guarantee against any lack of food during the growing period, and thus make the conditions of climate and season, rather than the soil, the measure of the crop. That is, as far as practicable, the yield that it is possible to obtain in a given locality should be the aim of the farmers in that locality. In order to make the conditions of soil perfect in this respect, the fertility elements must be added, though indirect manuring, in the form of better cultivation and better use of the waste products of the farm, are also to be encouraged.

A greater demand for special crops.

In the second place, farming to-day consists of much more than the simple production of the staple crops. Changed conditions are shown very clearly in the increased demand for medicinal plants, nuts, nursery stock, market-garden products, fruits, and special poultry, dairy and swine products. Not so many years ago the staple crops already described were practically the only ones raised and sold from the farm.

For example, the growing of vegetables and fruits was limited. They were regarded as luxuries, and the area given to them was, on most farms, only sufficient to meet the needs of the home. These were not regarded

as crops in the same light as the others, and were seldom the source of direct income. At the present time, vegetables and fruits are regarded as necessities in every home, and their use is not confined to the season in which they can be provided in the immediate vicinity of the cities or towns where they are used; they are drawn from points far distant, and the demand is such as to require the use of wide areas in order to supply the needs. The growing of market-garden crops and fruits is now the basis of specific agricultural industries which have assumed large proportions.

Much progress has been made, too, in the development of methods of practice in these lines of farming, and the experience gathered has shown that even our most fertile soils in their natural conditions contain too little active food to insure maximum yields of crops of the best quality; in these lines of farming, too, earliness and edible quality of products, which are influenced by the food supply, are important factors in determining the profits to be derived. The areas now necessarily devoted to these crops are so great that soils of a high natural fertility, even if natural fertility alone could be depended upon, are too limited to meet the demand and enable a profit, especially in the vicinity of good markets; in other respects a good location, because permitting of cheap distribution, is an important factor.

Farm manures are inadequate.

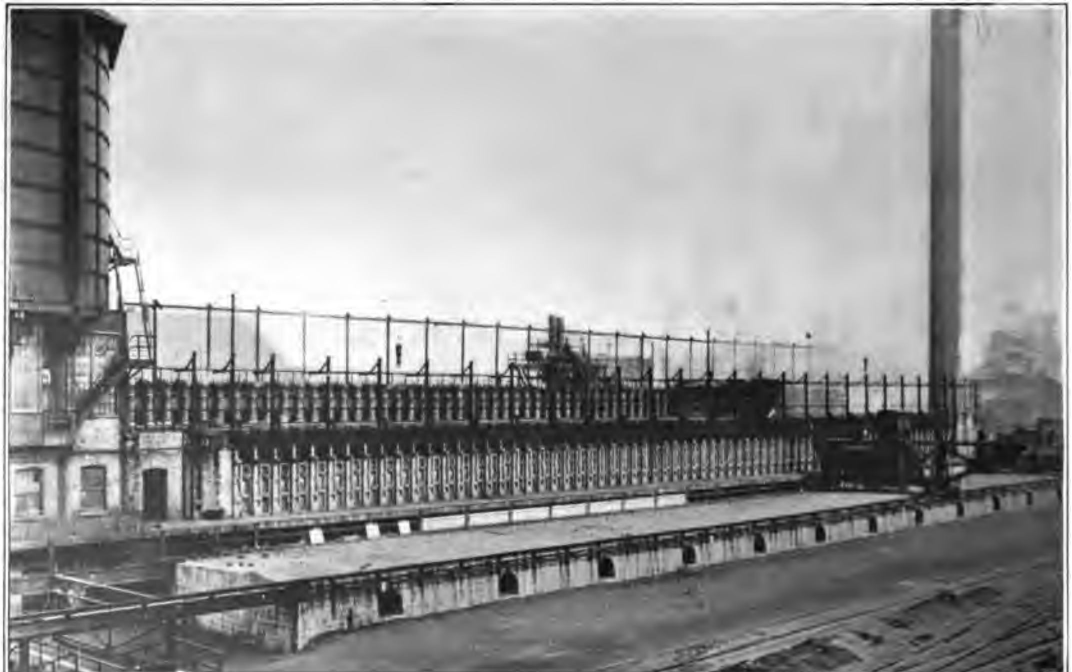
Farm manures might meet the needs for the staple crops, as they are well adapted in many respects for the purpose, but, under present systems of management, the amount is not sufficient to meet the annual losses from the sale of crops, much less to provide an

increase, and the only other source is an artificial supply, or commercial fertilizers. For the special crops already described, the natural manures of both farm and city are not only not sufficient, but, because of their character and composition, are not well adapted to meet economically the entire demands of the plants. In the first place, they are bulky, and thus expensive to handle. In the second place, the fertility elements contained in them are not in good proportion; they are, as a rule, poor in the mineral elements and rich in nitrogen, and their use in sufficient amounts to meet the needs of the plant for the mineral elements results in a waste of the nitrogen. Third, the constituents contained in them are not in sufficiently active forms to provide for a rapid and continuous growth without an excessive application, which frequently results in a serious waste not only of the nitrogen, as already indicated, but, in the case of many crops, an abnormal growth of vine or stalks, which may seriously injure the marketable quality of the crops. For many crops, economical production requires that the natural manures be supplemented by artificial supplies, by means of which the form and amount of the individual constituent can be regulated to meet the needs of the various plants.

The growing importance of fruit-growing.

In fruit-culture, an industry of growing importance, it has been found that soils in their natural condition, while they may be well adapted in other respects, — that is, possess a suitable physical character for the growth of this class of crops, — contain insufficient amounts of the mineral constituents which are required in order that continuous and large crops of perfect fruit may be secured. To supply this deficiency farmyard manure

PLATE I. FIG. 1.—Coke-oven Plant, Gary, Indiana, where ammonium sulfate is an important by-product.



would cause in many cases an over-supply of vegetable matter containing nitrogen, which for these crops is frequently followed by disastrous results, not only causing an abnormal growth of leaf and wood, but inducing it at such periods of the year as to materially interfere with the proper ripening of both the wood and the fruit. By the use of artificial fertilizers, these difficulties may be largely overcome.

WILL IT PAY TO USE FERTILIZERS?

It must be confessed that to give a definite and positive answer to this question, with our present state of knowledge, is a difficult matter, if not well-nigh impossible, because of the very large number of varying conditions that are involved.

Usually such a question cannot be answered in a rational way without first securing definite information concerning the conditions under which they are to be applied, as, for instance, the character of soil, whether a sand, clay or loam; situation in reference to moisture, whether too dry or too wet; the kind of subsoil, whether a loose, open sand or gravel, a medium clay or a tight, impervious hard-pan; the character of the previous treatment and cropping, whether the land has been manured or fertilized, whether good cultivation has been practiced, whether leguminous crops have been grown to any extent, whether the produce raised has been sold, or fed on the land; whether the object of the growth has been for immature produce and for early market, and artificial growth demanded, or whether for maturity, when the natural tendency has simply been assisted and the development normal in all directions.

If these questions are answered truthfully and in detail, a scheme of fertilization may be adopted that will enable the farmer to secure the greatest returns for the plant-food applied.

That the returns from the use of fertilizers are frequently unprofitable is not always the fault of the fertilizer, and this point may be illustrated by the following typical case: One farmer applies plant-food, his crop is doubled or trebled, and a reasonable profit is secured. Another farmer applies the same amount and kind of fertilizer under similar natural conditions of soil, and he receives no benefit. The same climatic conditions surrounded the crops of both: the sun that warmed the soil and furnished the energy necessary for the production of the largely increased crop is the same sun that shone upon the small crop; the air that furnished a large proportion of the food for the one is the same air that surrounded the other; the rains that moistened and assisted in the solution and circulation of plant-food for the one were the same for the other. Why, then, the difference in results? In one case the natural agencies, sun, air, and water, were assisted and enabled to do their maximum work, while in the other, they were prevented from exercising their full influence. Physical conditions of soil were imperfect, due to careless plowing, seeding, cultivation and cropping.

In other words, the profit from the use of plant-food is measured to a large degree by the perfection of soil conditions, which are entirely within the power of the farmer to control. The production possible from a definite amount of plant-food can be secured only when the conditions are such as to permit its proper solution, distribution and retention by the soil.

The fact that fertilizers may now be easily secured, and the ease of application, have encouraged a careless use, rather than a thoughtful expenditure, of an equivalent amount of money or energy in the proper preparation of the soil. Of course, it does not follow that no returns are secured from plant-food applied under unfavorable conditions, though full returns cannot be secured under such circumstances. Good plant-food is wasted, and the profit possible to be derived is largely reduced.

Again, because farming, in its strict sense, is the conversion of three essential elements into salable products, the time to apply plant-food must be governed largely by its cost and the kind of crop upon which it is applied.

CHAPTER III

NITROGENOUS FERTILIZERS

NITROGEN is the most expensive constituent of fertilizers, and, all things considered, it is one of the most useful. Nitrogen exists in nature as a component of the air, and though quite as necessary to vegetation as carbon or oxygen, — which also exist in the atmosphere, and which are readily acquired by all plants, — all plants do not have the power of acquiring nitrogen from this source. This power seems to be limited to a class of plants called Leguminosæ, to which belong the various clovers, peas, beans, vetches and a number of others. The important farm crops belonging to the other botanical groups of plants obtain their nitrogen largely, if not altogether, from the soil.

Vegetable or animal matter containing nitrogen may serve as a source of nitrogen to plants, though it cannot feed them with this element to any extent until it decays or rots. In order to obtain a clear conception of the use of nitrogen as a fertilizer, one should understand the need of plants for it, what is meant by form of nitrogen, and the sources from which the various forms may be derived, as well as the relative agricultural or crop-producing value of the nitrogen in existing commercial forms.

WHAT IS MEANT BY FORM OF NITROGEN?

Strictly speaking, form of nitrogen has reference to its combination or association with other chemical elements, though sometimes the term "form" is used to indicate rate

of solubility, which also measures to some degree availability, since it happens that soluble forms of nitrogen are really more available than the insoluble forms, though neither the soluble nor insoluble forms show the same rate of availability; that is, a pound of soluble nitrogen is not equally available from whatever source derived, and a pound of insoluble from one source may be much more available than a pound from another. The form in which nitrogen exists in vegetable and animal matter is called the "organic form," because it is associated with other constituents, as carbon, hydrogen and oxygen, which are necessary to make the substances that constitute animal or vegetable matter. The term "organic," as applied to nitrogen, covers a whole series of substances, and does not indicate a uniformity, either in content or quality of the nitrogen, as is the case with distinct chemical compounds; hence, associated with the knowledge of form of nitrogen, when it exists in organic products, must be a knowledge of whether the material contains a very considerable amount of nitrogen, and whether it is likely to be readily changed, and thus become available as food for plants.

Any nitrogenous vegetable or animal matter may serve as a fertilizer, though organic nitrogen in commercial fertilizers is usually obtained from products relatively rich in this constituent, and it is only these that can be used to advantage in making what are known as "high-grade fertilizers." The leading animal substances of this class are now mentioned.

DRIED BLOOD

One of the most important products from which organic nitrogen is derived for commercial fertilizers is dried blood.

It is important not because the supply is large and the price low, but because it is one of the most concentrated, one of the richest in nitrogen of the organic nitrogenous fertilizing materials. It is one of the best, since its physical character is such as to permit of its very rapid decay in the soil during the growing season. This tendency to decay rapidly is plainly apparent, when it is remembered that blood as it exists in the animal is in fluid form, and naturally any material which is sufficiently finely divided to permit of its ready flow, and is not associated with any hard or fibrous material, possesses characteristics which enable a rapid breaking down when subjected to the proper temperature and moisture conditions which promote decay.

Dried blood for fertilizing purposes is chiefly obtained from the large slaughtering establishments. The markets recognize two distinct kinds, red and black. The former is carefully dried with hot water and contains 13 to 14 per cent of nitrogen. It is uniform in composition and because of its quality commands the higher price. It contains only traces of phosphoric acid. The market product is standardized and guaranteed to contain 16 per cent ammonia. The latter — black blood — is dried at a higher temperature with less care, which gives it a darker color and leathery character. It also contains considerable impurities, such as bone. It contains from 6 to 10 per cent of nitrogen and often as high as 4 per cent of phosphoric acid. In this case, also, the market product is standardized and guaranteed to contain 12 per cent of ammonia.

The red blood is considered a high-grade fertilizer material, uniform in composition, high in nitrogen and of excellent mechanical texture. The black blood, while

considered better than many other organic nitrogenous materials, is less concentrated and less uniform. It is unfortunate from the farmer's point of view that the supply of these materials is decreasing so rapidly.

DRIED MEAT OR MEAL, AZOTIN, AMMONITE OR ANIMAL MATTER

Dried meat or meal, azotin, ammonite or animal matter, are terms applied to practically the same product produced at rendering establishments, where the different portions of dead animals are utilized. These are subjected to treatment, usually dried and extracted with steam, for the purpose of securing the fat, though formerly, and even now, a large portion of this product is obtained from the beef extract factories. When relatively pure it contains 13 to 14 per cent of nitrogen and compares favorably with blood. When the use of fertilizer was less and the supply relatively greater this was an important product. To-day it is seldom heard of and the market does not recognize it as such.

This product, very limited in supply, is reasonably uniform in composition, containing as high as 12 per cent of nitrogen, and ranks among the high-grade materials. It is considered superior to leather, wool or hair.

DRIED AND GROUND FISH, OR FISH GUANO

Ground fish is obtained from two sources: first, from the offal, largely bones and skins, of fish packing or canning houses; and second, from the fish pomace resulting from extraction of the oil from the Menhaden. The latter product is richer in nitrogen and is more uniform in character than the wastes from the packing houses. Dried

ground fish from this source contains from 7 to 8 per cent of nitrogen, and from 6 to 8 per cent of phosphoric acid. The former, owing to the varying proportions of bone, skin and flesh contained in it, varies widely in its content of nitrogen. Fish, besides affording a considerable supply of nitrogen, is also regarded as a good source of this element, ranking in availability well up to blood.

The use of these materials is more common along the coast, where fishing is an important industry. The supply of fish pomace is to a marked degree regulated by the abundance of Menhaden, which varies greatly from year to year. More profitable use may be made of these products if applied a few days before planting upon soils which present conditions favorable to decomposition.

TANKAGE

Tankage is a highly nitrogenous product, and consists chiefly of the dried animal wastes from the large abattoirs and slaughtering establishments. It is variable in its composition, since it includes the otherwise unusable parts of the carcass, as bone, tendons, flesh, hair and the like. The portions of this from the different animals not only vary in their composition, but they are used in varying proportions, which naturally results in an extremely variable product. What is known as "concentrated tankage," which is obtained by evaporating the fluids which contain certain extractive animal matter, is the richest in nitrogen, and is more uniform in character than the others; and because of its fineness of division and physical character, the nitrogen contained in it is also more active than in the other forms. Two distinct kinds of tankage can, therefore, be obtained: first, concentrated

tankage, which is the richer in nitrogen, ranging from 10 to 12 per cent, and which contains very little phosphoric acid; and second, crushed tankage, which is of several grades, ranging from 4 to 9 per cent nitrogen, and from 3 to 12 per cent of phosphoric acid. Products are sometimes sold as tankage, which contain much more than the maximum of phosphoric acid and less than the minimum of nitrogen here given, in which case they are to be classed with bone, rather than with tankage. Tankage varies so much, both in its content of phosphoric acid and nitrogen, that in the trade it is always sold on the basis of its composition. The percentage of nitrogen and phosphoric acid is distinctly stated, and because it contains very considerable amounts of phosphoric acid, its commercial value is not wholly based on its content of nitrogen, as is the case with dried blood, dried meat and concentrated tankage.

The market recognizes several distinct grades indicated by the following guarantees:

Percentage of Ammonia	Percentage of B. P. of L.	Percentage of Nitrogen	Percentage of Phosphoric Acid
11	20 equivalent to	9.0	9.15
9	20 equivalent to	7.4	9.15
7	30 equivalent to	5.8	13.75
7	15 equivalent to	5.8	6.80

Care should be taken in the purchase of tankage because it is sometimes mixed with garbage tankage, a material less valuable and more variable. Adulterations of this kind are not easily detected. They are more common in the less concentrated tankage products.

GARBAGE TANKAGE

While this material is considered a low-grade product, it is, nevertheless, important because the supply is increasing annually. It is manufactured from kitchen wastes of the cities, sometimes by drying, sometimes by partial charring, but more often it is a by-product after treatment to extract oils and greases. However derived, it is very variable in composition and its value as a fertilizer differs with its content of the elements of plant-food. It is now used to considerable extent in the manufacture of commercial fertilizers and sometimes as an absorbent in stables, but for this purpose it lacks the desired quality of cleanliness and often carries disagreeable odors. Analyses show that it may contain as high as 2.5 to 3 per cent of nitrogen, 1.5 to 3 per cent of phosphoric acid and .75 to 1.5 per cent of potash.

LOW-GRADE NITROGENOUS PRODUCTS

Other products which contain a high content of nitrogen are frequently used. These, because of their low rate of availability, constitute a separate and distinct class.

Horn meal, or *ground horn*, is reasonably uniform in its composition or content of nitrogen. It contains as high as 10 or 12 per cent of nitrogen, but it is slow to decay when used in its natural state, and, therefore, is not regarded as an economical source of this element, unless it can be obtained at a low price.

Leather meal is another product which is rich in nitrogen, but which is so slow to decay that its use in the natural state is not recommended. One object in making leather is to render it resistant to the conditions which promote

decay, and ground leather may remain for years in the soil in an unchanged condition.

Wool and *hair waste* are also products which exist in considerable quantities, and while variable in composition, are frequently rich in nitrogen, but they are classed with leather because of their slow activity. Their mechanical form, coarse and bulky, makes it impossible to use them to advantage in the manufacture of fertilizers without previous treatment. The use of these materials, untreated, can only be regarded as desirable when they may be obtained at a very low cost. When dissolved with acid, or treated in such a way as to render them more immediately available, they may be used to advantage, though the cost of such treatment is usually so great as to make it impossible to thus improve their form and still be able to compete commercially with the other nitrogenous products.

VEGETABLE NITROGENOUS PRODUCTS

Cotton-seed meal is one of the best organic nitrogenous fertilizing materials derived from vegetable life. When oil is extracted from cotton-seed, the residue is ground fine and sold as a food for cattle and as a fertilizer. Because it is highly valued as a food for cattle, it has been standardized to contain 38 to 42 per cent protein, equivalent to 6 to 7 per cent nitrogen. It contains besides the nitrogen often as much as 3 per cent of phosphoric and 2 per cent of potash. When mixed with hulls the percentages of the elements of plant-food are lower. Tests made show that it ranks with blood in the availability of its nitrogen. Its use as a fertilizer is confined largely to the southern states, where cotton is a staple crop, and

it may be secured in abundance without cost of transportations. Furthermore, its use as a food for cattle is becoming more thoroughly understood and appreciated so that its use as a fertilizer is decreasing.

Linseed meal is a material somewhat similar in character to cotton-seed meal. It contains on the average 5.5 per cent of nitrogen. The demand for this product for feeding purposes at good prices makes it, however, an expensive source of nitrogen.

Castor pomace, the waste resulting from the extraction of oil from the castor bean, is also a valuable nitrogenous fertilizer. It contains, on the average, 6 per cent of this element, and decays rapidly in the soil. This product differs from the cotton-seed and linseed meal, in that it is not useful as a cattle food. Practically its only use is as a fertilizer.

Vegetable pomaces. — There are a number of pomace materials of local interest, including apple pomace, tomato pomace, pumpkin pomace, cranberry pomace and the like, which are used to a considerable extent by a few individual farmers. These materials are very variable in composition. They are usually used without drying and the content of moisture is almost never constant. Most of these products are derived from fruits or vegetables very acid in character and the acid contained is often in large enough quantities to be injurious unless composted with dirt and slaked lime.

NATURAL GUANOS

A series of nitrogenous products which constitute still another separate class, consists of the various natural guanos. From its derivation the word "guano" means

dung, and it is probably one of the oldest materials used as a fertilizer. Its use dates back to the twelfth century, but it was not until the middle of the nineteenth century that its value became generally appreciated. The first shipments were made from Peru to European ports late in the year of 1840. The use of these products spread rapidly and were considered a valuable source of nitrogen, though at the present time they are not commercially important, owing to the practical exhaustion of the best supplies. Of the guanos, the product obtained from Peru, or from the islands on the coast of that country, is the richest in nitrogen. It is derived from the excrements and bodies of sea-fowls.

When the deposits occur in regions which are warm and with little rainfall, they are high in nitrogen, especially if considerable time has elapsed since their formation. Where rainfall is more plentiful, even occasional, the nitrogen is readily changed by microörganisms to soluble forms which are leached away together with the potash salts, leaving a product low in nitrogen and high in phosphoric acid. The first product usually contains from 12 to 14 per cent of nitrogen and from 10 to 12 per cent of phosphoric acid, whereas the second product contains from 5 to 8 per cent of nitrogen and from 20 to 25 per cent of phosphoric acid. It must be remembered that guanos are variable and each successive consignment shows a different composition. In fact, the composition of these materials is of a very complex character. The nitrogen exists largely as ammonia, combined with oxalates, urates, humates, sulfates, phosphates, carbonates, and to some extent in purely organic form. In these forms the nitrogen is quickly available, and marvelous results are obtained from their use.

There are many other deposits of guano, but none has been found which are so valuable as the Peruvian. Ichaboe guano, for example, is at present exported, though it is a fresh deposit, and is annually collected for shipment. Bat guano found in caves in Mexico and in some of the southwestern states is another example. Both are inferior to Peruvian guano. They contain less nitrogen and a very considerable amount of insoluble matter, though the nitrogen is usually in a good form. In the case of the latter, a considerable portion exists as a nitrate. Owing to the very excellent results that were obtained from the early use of guanos, many attempts have been made to improve the lower grades obtainable at the present time, by the addition of nitrogenous matter of a higher rate of availability. These rectified or fortified guanos, while containing nitrogen in good forms, cannot entirely substitute the original guanos, owing to the impossibility of adding forms identical with those existing in the natural product. That is, the total content of nitrogen in a rectified guano may be the same as in the genuine product, though the special forms and their proportions cannot be simulated. The distinctive value of the natural guanos is due to the fact that the nitrogen existed in a number of different soluble compounds, which became available at different times in the soil, and thus constantly fed the plant with this element. The fact that nitrogen guanos gave such good results is an evidence of the advantage of introducing different forms into artificial mixtures.

It is argued that because of the very great value of guanos, which consist very largely of the excrement of fowls, that droppings of pigeons, particularly, and of domestic fowls should also possess a high value, and for

this reason a rather fictitious value has been fixed upon these products. These products differ very materially from natural guanos, and it is due probably both to the character of the food eaten by the domestic fowl, and to the different methods by which the material is obtained. The birds producing the guanos feed largely upon fish, a highly nitrogenous food, resulting in an excrement richer in this element than that from the domestic bird, feeding largely upon vegetable matter; and, besides, the former were accumulated in a hot, dry climate, which quickly absorbs the moisture contained in the fresh droppings, thus leaving it in a much drier state than is the case with the domestic product.

MECHANICAL CONDITION SHOULD BE CONSIDERED

It will be observed from the foregoing brief description of the chief sources of organic forms of nitrogen, that a very wide variation occurs both in the composition or content of nitrogen in these products, and in the availability of their nitrogen, or rapidity with which, under similar conditions, it is given up to plants. The fact that a substance contains nitrogen in considerable amounts and in an organic form, then, is not a sufficient guide as to its usefulness. Its mechanical condition, or physical form, must also be taken into consideration, and, other things being equal, the tougher and denser the substances, the longer the time required to decay, and hence the more slowly will the material feed the plant.

AMMONIA COMPOUNDS. See Fig. 1, Plate 1.

As already stated, nitrogen does not feed the plants in organic forms; it must first decay. The first prod-

uct of the decay of a nitrogenous organic substance is ammonia, a combination of two elements, hydrogen and nitrogen. As the organic animal or vegetable substance which contains carbon, hydrogen, oxygen and nitrogen in combination breaks up, the carbon combines with part of the oxygen to form carbonic acid; part of the hydrogen also combines with oxygen to form water, and the nitrogen combines with hydrogen to form ammonia. Yet even in this form, plants do not absorb it freely. Ammonia is in a better form than the organic material, because, in the first place, it is soluble in most of its combinations with other substances, and is thus readily distributed in the soil, and in the second place, it is very liable to change. That is, its future availability is no longer dependent upon any mechanical or physical form; every portion or pound of ammonia is as good as any other portion or pound. Ammonia, however, does not occur as a natural product, like the organic forms, blood, meat and fish. Commercial forms are the result of a manufacturing process, and they may exist as distinct chemical substances; as sulfate of ammonia, in which case the ammonia is combined with sulfuric acid; as chlorid of ammonia, in which case it is combined with hydrochloric acid; as nitrate of ammonia, in which case it is combined with nitric acid; and as carbonate of ammonia, in which case it is combined with carbonic acid.

Sulfate of ammonia is a chemical salt which, when pure, contains 21.2 per cent of nitrogen. In commercial forms, however, it usually contains about 20 per cent of nitrogen. It is obtained from the dry distillation of animal bone in the manufacture of bone-black, from the distillation of coal in the manufacture of illuminating gas, and from coal in the manufacture of coke. The

quantity now made is increasing annually, largely because of the improved methods used in the manufacture of coke, which permit the saving of the ammonia. Its chief advantages are that it is very concentrated, therefore reducing the cost of handling; it is always in the same form, a distinct and definite product, thus rendering its purchase a safe proceeding; and it is very quick to act, thus making it a very useful form, especially for quick-growing crops. Its physical character is such as to permit its ready distribution in a mixture. On the other hand, it should not be mixed with an alkaline material, in which case the ammonia is liberated. Such substances are wood-ashes, basic-slag, potassium carbonate and slaked or burned lime.

Calcium cyanamid is not an ammonia compound, but it is thought wise to consider it here because it is believed that it undergoes a gradual change when brought in contact with soil moisture and forms ammonia. It is a comparatively new product made possible by the developments in the world of electricity. This material, sometimes called lime-nitrogen, is now being manufactured, by two plants in this country. In its manufacture finely divided calcium carbide is placed in a heated retort, into which nitrogen, obtained by liquefaction of air and distillation, is passed. The resultant material is removed in the form of a hard cake which is finely ground, and after thorough aëration is ready for distribution. When calcium cyanamid is free of impurities it contains 35 per cent of nitrogen, but the commercial product seldom exceeds 15 per cent. While its availability ranks with other ammonium salts it has the disadvantage of causing injury to young plants unless it is distributed in the soil some time before planting.

Differing from sulfate of ammonia it tends to sweeten soils rather than cause a more acid condition.

If calcium cyanamid is used to supply a part of the nitrogen in a complete fertilizer, the analysis will be somewhat misleading. In the chemical analysis, the form in which the nitrogen derived from cyanamid would be reported would depend upon the amounts and forms of nitrogen derived from other sources used in the mixture. If nitrate of soda is used in the mixture, the amount of nitrate nitrogen reported will be greater than the actual amount derived from nitrate of soda, a portion being obtained from the cyanamid. This same condition is true when ammonia salts are used, a part of the nitrogen from cyanamid would be reported as ammonia nitrogen. In either case the remaining portion of nitrogen from cyanamid would be reported as water-soluble organic nitrogen.

NITRATE NITROGEN

Neither organic nor ammonia compounds containing nitrogen are capable of fully meeting the demands of plants for this element. The first, or organic nitrogen, must pass through two changes, first to ammonia, and then to nitrate, and the ammonia must change to a nitrate.

This process already referred to is known as nitrification. The nitrate is directly absorbed by plants, and the larger portion obtained by them is taken up in this form. Hence, from the standpoint of availability, nitrate nitrogen must be regarded as the most useful form. Like ammonia too, a pound of it is as good as any other pound, from whatever product it may have been derived. It is a relatively concentrated material; and as it is perfectly

soluble, it readily distributes itself everywhere in the soil to which it may be applied.

Nitrate of soda. — There are a few substances found in nature containing nitrogen in the nitrate form. The most important is nitrate of soda, a chemical compound composed of sodium, oxygen and nitrogen. The occurrence of this material is limited to the rainless districts of South America, mainly Chile, where the crude nitrate of soda salts called Caliche are found in vast quantities. These crude salts contain from 5 to 30 per cent of nitrate of soda. In the process of refining for market they are dissolved and recrystallized in order to remove as far as possible the impurities associated with them. There are great quantities of a lower grade containing 3 per cent or less of nitrate of soda which are not at present considered sufficiently rich to refine. The chemically pure salt, nitrate of soda, contains 16.47 per cent of nitrogen, and the commercial article, called "Chili saltpeter," contains from 15.5 to 16 per cent. The impurities which remain in it consist mainly of sodium chlorid, or common salt, which, together with moisture, causes a lower percentage in the commercial product. Because nitrogen in nitrate of soda is in the nitrate form and, therefore, soluble, it is often advanced that there is greater loss from leaching into the drainage waters. Experiments show this is untrue or at any rate the efficiency of this material is greater than that of any other because more is returned in the crop as shown in the discussion of relative availability of the forms of nitrogen which follows. When nitrate of soda is mixed with other materials it has a tendency to cause a caking or hardening of the mixture, but this is no more true of nitrate of soda than of the potash salts. Unlike ammonium sulfate, nitrate of soda

leaves in the soil an alkaline residue rather than an acid residue.

The search for deposits of crude nitrate salts in other parts of the world has been rather fruitless, but it has been known for a long time that nitrate exists in Egypt and India in combination with potassium rather than sodium, which makes these deposits even more valuable because potassium is more valuable than sodium in these countries. Very recently nitrate beds have been reported in some parts of California, but the reports of the composition of the raw material have been unfavorable. If the most convincing theory of the formation of the nitrate beds is to be accepted, — namely, that gigantic islands of sea-grass in the ocean became isolated by volcanic rising of the ground, and subsequently the sea water evaporating they remained and decayed, — it is not probable that new beds are in the process of formation as in the case of the guanos of Peru. But there is little cause for alarm because experts claim the Caliche beds of Chile will last from 300 to 400 years before the higher grade salts become completely exhausted at the present rate of consumption.

Calcium nitrate is a manufactured product of comparatively recent origin containing its nitrogen in the nitrate form. It has caused much confusion because many names have been applied to the same material; as, nitrate of lime, lime-saltpeter, basic calcium nitrate, lime-niter, basic nitrate, and basic lime-nitrate. It is now being manufactured in Norway, Austria, France and the United States from atmospheric nitrogen. The commercial product is a mixture of lime and calcium nitrate containing 12 to 14 per cent of nitrogen, though it often varies as much as from 9 to 14 per cent of nitrogen.

Potassium nitrate. — It has already been stated that potassium nitrate salts exist in Egypt and India. They are also found in Cape Colony, South Africa. The impure salts on the market, commonly called niter or saltpeter, contain 14 per cent of nitrogen and 44 per cent of potash. Because this material is used for manufacturing purposes, especially gunpowder, little is sold for fertilizer even though it is especially concentrated considering its content of both nitrogen and potash.

Ammonium nitrate is a compound now being manufactured in Norway which is superior to the other nitrogenous products in that it is highly concentrated and leaves no injurious residue in the soil. Chemically pure, it contains 35 per cent of nitrogen, one-half in the ammonia form and one-half in the nitrate form. The commercial product, yet limited in quantity, is sold on the dry basis 99.8 per cent pure. At the present time, the cost of nitrogen contained is too high to warrant the use of this material as a fertilizer.

THE RELATIVE AVAILABILITY OF THE DIFFERENT FORMS OF NITROGEN. See Fig. 2, Plate 2.

From this discussion of the kind and source of nitrogenous fertilizer supplies, it is shown that the form of the nitrogen is an important factor in determining the rate at which the plants may obtain it. In the case of nitrate, the form is such as to enable the plants to take it up immediately. It is, therefore, theoretically the best, because as soon as it comes in contact with the roots, it is absorbed by them; there is no appreciable time required to enable the element to get into a condition capable of ready absorption by the plant. Furthermore,

its extreme solubility makes it possible, when moisture conditions are good, to reach every portion of the soil in which the roots are located, so that it is not only more available by virtue of its being in the right form, but because it readily goes to the place where the plant roots are. The next substance in order of availability is ammonia, and the rapidity with which ammonia will change to a nitrate makes it under many circumstances quite as useful. It possesses, also, one great advantage possessed by the nitrate, that of being soluble in water, and thus readily distributes itself throughout the surface soil. The difference in usefulness of these two forms seems to depend more largely upon the character of the season than upon the exact form. In a very wet season the nitrate is less useful, because liable to be washed below the reach of the roots, or lost altogether, and in a dry season it is more useful than the ammonia, because as soon as it is in solution it is capable of being absorbed. It must be remembered, however, that these two forms possess the further advantage over organic forms, that they are definite chemical compounds, which always possess the same characteristics, and under similar conditions they always act in the same way. If nitrogen is purchased as ammonia, the source of the nitrogen is not important; that is, whether derived from the manufacture of illuminating gas, coke, or bone-black, or from one of the newer ammonia compounds, if it is ammonia, it is identical in character. The same is true of nitrate — the original source of the nitrogen is immaterial.

The availability of nitrogen in organic forms, as already pointed out, depends upon the rapidity with which they will change to the nitrate under varying conditions.

PLATE II. FIG. 2. — Cylinder Experiments at the New Jersey Agricultural Experiment Station.

Such products as dried blood, dried meat, dried fish and concentrated tankage change rapidly, and are, therefore, good forms, while products like raw leather and horn meal are very slow to change.

The practical point, and the one of prime importance to the farmer, is, then, to know how to estimate the relative value or usefulness of these different products, what is the rate of availability as compared with nitrate, and thus the relative advantage of purchasing the one or the other, at the ruling market prices. Relative values, however, cannot be assigned as yet, though careful studies of the problem have been made, chiefly by what are known as "vegetation tests"; that is, tests which show the actual amounts of nitrogen that plants can obtain from nitrogenous products of different kinds, when they are grown under known and controlled conditions. An enormous amount of work has been devoted to the comparison of the availabilities of the nitrogen of the different substances under different conditions and with different crops, and tables have been prepared showing the relations thus observed. The comparative availabilities are established in these tables by taking the yield from nitrate nitrogen at 100, and using this as a standard for measuring the yields from other substances. It will be seen, therefore, that the actual availabilities are smaller than the comparative availabilities, since the return from nitrate nitrogen never actually reaches 100 per cent. Furthermore, while practically all of the effect from the application of nitrate or ammonia nitrogen is obtained in the first season, the effect from manure nitrogen or other forms of organic nitrogen is often considerable in the second and even the third season — a fact which must not be overlooked in the study of availabilities. The following tables give

the results obtained by different workers under average conditions. It also shows the recovery of nitrogen from different forms. The values given are far from fixed, since changed conditions of soil, climate, crop and the like may modify them to a considerable extent. At all events, they are a fair approximation of the actual conditions as they exist in most soils.

Comparative availability of different nitrogenous substances.

AUTHORITY	WAGNER AND DORSCH	JOHNSON	VOORHEES	WAGNER	AVERAGE
Nitrate of soda . .	100	100	100	100	100
Sulfate of ammonia .	90	—	—	83	86
Cotton-seed meal . .	—	76	70	—	73
Dried blood . . .	70	77	70	65	70
Horn meal	70	72	—	65	69
Hoof meal	—	72	65	—	68
Dried fish	—	70	65	—	67
Green plant substance	70	—	—	65	67
Tankage	—	68	60	—	64
Meat meal	60	—	65	53	59
Bone-meal	60	—	65	53	59
Stable manure . .	45	—	—	25	35
Wool waste . . .	30	—	Variable from 2 to 30	25	27
Leather meal . . .	20	—	Variable from 2 to 30	15	17

The author's figures in this table furnish a fair basis for comparing the different materials, when used for the same purpose or under the same conditions. If, for example, the increased yield of oats due to the application of nitrate of soda is 1000 pounds, the yield from blood and cotton-seed meal would be 700 pounds, the yield

from dried ground fish and hoof meal would be 650 pounds, from bone and tankage 600 pounds, and from leather, ground horn and wool waste, from 20 to 300 pounds.

The foregoing discussion shows very clearly that organic, ammonia and nitrate nitrogen have a very unequal value as sources of nitrogen. Nitrate nitrogen, the most valuable of all three, is seldom if ever entirely used by the crop. Conditions determine in a large degree the proportion of the nitrate nitrogen secured by the crop, because a smaller or larger amount escapes beyond the reach of the plant by leaching or into the air by denitrification. The amount of nitrogen returned by the crop in the harvest is, therefore, a direct means of determining the relative availability of nitrogen from the three different forms. Investigations conducted by Paul Wagner, Darmstadt, Germany, and the author, Edward. B. Voorhees, of the New Jersey Experiment Station, agree very closely. Conclusions from these works show that there was returned in the harvest 62 parts of nitrate nitrogen for every hundred parts applied; 44 parts of ammonia nitrogen for every hundred parts applied and 40 parts of organic nitrogen for every hundred parts applied as dried blood. Hence, with the returns from nitrate, the highest recovery regarded as 100, the relative availability of the nitrogen as ammonia would be 69.7 and of nitrogen as dried blood as 64.4. These figures possess great practical significance to the farmer buying and using the nitrogen now offered on the market in fertilizers.

Conditions which modify availability.

The foregoing discussion and figures alone are, however, not a sufficient guide as to the kinds to buy under all

conditions, since the usefulness of the different forms are also dependent upon such other conditions as the character of soil, kind of crop season and the object of the application.

The character of soil is an important factor. The mechanical composition of a soil is a dependable guide as to the rapidity of leaching of the soluble forms of nitrogen. A loose light soil permits more rapid percolation of water through it to the lower layers below the reach of plant-roots and nitrogen is more readily leached away than in heavier soils possessing finer particles. Furthermore, some soils naturally possess conditions favorable to nitrification, some possess similar conditions through the efforts of man, and still others possess conditions unfavorable to nitrification. Soils sufficiently open and porous to permit easy cultivation and proper circulation of air and moisture, and well supplied with lime and organic matter possess those characteristics favorable to the spread and development of bacteria which bring about a more rapid change of the form of nitrogen. Again, the previous treatment of a soil is an important consideration. Liberal applications of manure, and the production and use of leguminous crops for manurial purposes tend to build up the content of organic nitrogen in a soil so that less might be used at planting time.

The kind of crop is an important factor, since certain crops grow and develop quickly, while others grow for a comparatively long period. Some require greater quantities of food in a usable form and others feed more slowly. It is the object in some instances to produce succulence, in others to produce grain. The season, likewise, because the changes from organic forms to ammonia, or nitrate, only take place when the tempera-

ture reaches 37° F., and when in addition sufficient moisture is present. Hence, a material which might give excellent results when applied to a crop that grows through a long period in a climate where the season is very warm and moist, might be very unsatisfactory where the season is short, cold and dry. These are a few of the conditions which modify the rate of the decay of the same material.

The object of the application should also be taken into consideration. The rate of the feeding of the plant with nitrogen in organic forms is measured by the rate of decay of the organic material containing it, while when nitrate is used, its feeding is direct. The result is really a sort of feeding of the soil in the one case, and a direct feeding of the plants in the other. Where the purpose is to get the largest proportionate increase in crop from the least amount applied, either the nitrate, or the ammonia, or the more active of the organic forms, would be likely to give the best returns. Whereas, if the object to be attained is not so much a large increased crop as it is increase in the future productive capacity of the soil in respect to this element, the slower acting materials will often answer the purpose quite as well as the use of the more active nitrate form, because in this form no insoluble combinations are formed, the nitrate is freely movable, and if the plants do not absorb it, and heavy rains come, the water containing the nitrate is carried through the soil into the drains and the nitrogen lost. The disadvantage of the nitrate is, then, that there is a greater possibility of loss from its use than from the use of materials which are either insoluble, or which are readily absorbed. Ammonia, while perfectly soluble, is fixed by the other substances in the soil, and is not, therefore, readily leached out. If, however, heavy applications

are made, the possibility of loss is increased, because of the rapid change of the ammonia into the nitrate form. In the case of organic materials, the losses from leaching are seldom worthy of consideration in good practice, since an appreciable time is required, even in the case of the best forms, to change all of the nitrogen into ammonia, and then to a nitrate; while in the case of the poorer forms, still more time is necessary to cause the change, and losses are not liable to occur. In the making up of fertilizers, all of these considerations should be carefully balanced. It is the practice on the part of many manufacturers to use a part of each of the three forms, so that a continuous feeding of the plant may be insured. Therefore, while the fact remains that fertilizers containing only the one form may not be the poorest, the chances are that those which contain all forms are likely to give more satisfactory results.

CHAPTER IV

PHOSPHATES — THEIR SOURCES, COMPOSITION AND RELATIVE VALUE

MANY farmers apply the term "phosphate" to all manufactured fertilizers, without regard to the kind and character of the fertilizing constituents contained in them. The term "phosphate" should only be applied to materials which contain phosphoric acid, and it does not necessarily imply that the phosphoric acid is in an available form. The term "superphosphate" implies that the phosphoric acid contained in the material is available. The phosphates constitute a class of products from which superphosphates are made, and which are used in the manufacture of fertilizers that contain immediately useful or available phosphoric acid. The following discussion of phosphates is quoted from the author's "First Principles of Agriculture."

The phosphoric acid in artificial manures is derived from compounds called "phosphates." In phosphates the phosphoric acid is united with lime, iron and alumina, forming phosphates of lime, iron and alumina, as the case may be. The phosphates of lime are better calculated for the purpose, and are, therefore, used more largely than any other as a source of phosphoric acid, in the manufacture of artificial manures.

The phosphates available for this purpose are not, however, pure salts, but exist in combination either

with organic substances, or with minerals, or both, the content of phosphoric acid and its combination with other substances determining the usefulness of the phosphate to the manure-maker.

The phosphoric acid in these materials is soluble with difficulty in the soil water; and hence in their original condition, or in the crude raw forms, they give up this element in proportion as they decompose or decay in the soil. Those in combination with organic substances, either animal or vegetable, are, as a rule, more quickly useful as a source of phosphoric acid than those composed entirely of mineral constituents.

PHOSPHATE OF LIME, OR BONE PHOSPHATE — ANIMAL BONE

The bones of animals are the chief source of phosphates that exist in combination with organic matter, and were for a long time the main source for manurial purposes.

Bone consists chiefly of three classes of substances; viz., moisture, organic matter, containing nitrogenous and fatty matter, and phosphate of lime, or bone phosphate — the proportion, particularly of the nitrogen and phosphoric acid, depending upon the kind of bone and the method of its treatment.

Bone from the same kind of animal differs in composition according to the age of the animal and its location in the body. In a general way, the younger the animal the softer the bone, the poorer in phosphate of lime and the richer in nitrogen; the older the animal, the richer in phosphate of lime and the poorer in nitrogen. The large and hard thigh bones of an ox, for instance,

differ in composition from the softer and more porous bones of other parts of the body.

The phosphate of lime of the harder bones is dense and compact; that from the softer bone is more open and porous. The chief cause of variation in the composition of bones used as manure, however, is due to the treatment they receive. This is recognized by manufacturers and dealers, and different names of brands are used to indicate the method of manufacture or treatment. As applied, however, they do not always correspond to the methods of treatment.

Raw bone.

The term "raw bone" is properly applied to bone that has not suffered any loss of its original constituents in the processes of its manufacture, and is for this reason highly regarded by farmers, who believe that it is purer than any other form. This is true in a large measure, though the fact that it is raw bone is not altogether an advantage from the standpoint of usefulness. Raw bone too often contains considerable fatty matter, which makes it a difficult process to grind it fine, and which also has a tendency to retard the decay of the bone in the soil. A considerable amount of fat also reduces proportionately the percentage of the valuable constituents, phosphoric acid and nitrogen. Good raw bone, free from meat and excess of fat, should contain on the average 22 per cent of phosphoric acid and 4 per cent of nitrogen.

Fine bone.

The trade terms "bone meal," "bone dust" and "fine bone" are used to indicate mechanical condition,

or fineness of division, and do not refer especially to composition. These names should not be taken as indicating the fineness without personal examination, since frequently the products do not, in this respect, correspond to the name.

Boiled and steamed bone.

The larger portion of the bone used as manure has been boiled or steamed for the purpose of freeing it from fat and nitrogenous matter, both of which are products valuable for other purposes. The fat is, of course, of no value as a manure, and its absence is an advantage. The nitrogen, while useful as a manure, is extracted chiefly for the purpose of making glue and gelatine.

By boiling or steaming, the bone suffers a loss of its original constituents, the chief result of which is to change the proportions of the nitrogen and phosphoric acid contained in it. Steamed or boiled bone contains more phosphoric acid and less nitrogen than raw bone, and is also more variable in composition, the relative percentage of these constituents depending upon the degree of steaming or boiling to which the bone has been subjected.

Bone that has been used for the purpose of making glue, where the chief object is to extract the nitrogenous matter, contains from 28 to 30 per cent of phosphoric acid and from $1\frac{1}{4}$ to $1\frac{3}{4}$ per cent of nitrogen. The steaming of bone, particularly when conducted at high pressure, also exerts a favorable effect upon the physical and mechanical character of the bone. It destroys its original structure, makes it soft and crumbly, and often reduces it to a finer state of division than can be readily accomplished by grinding; and, since it is also free from fat,

and is finer, it is more directly useful as a source of phosphoric acid to plants than purer raw bone.

In some cases, the fat is extracted from bone by means of such solvents as petroleum or benzine. These methods of extracting the fat have the advantage of increasing the relative proportion of the nitrogen, this element not being attacked by the solvents. The more complete extraction of the fat and moisture by these methods also aids in the final preparation of the bone by grinding. Bone prepared in this way frequently contains as high as 6 per cent of nitrogen and 20 per cent of phosphoric acid.

The nature and composition of animal bone is such as to make it a valuable source of phosphoric acid; and, while it is largely used with nitrogenous and potassic materials in the manufacture of artificial manures, its best use is, perhaps, in the fine ground form, particularly for soil improvement and for slow-growing crops.

Phosphoric acid applied in this form gradually gives up nitrogen and phosphoric acid to the plant; and its physical and chemical characteristics are such that it forms in the soil, during the growing season, no compounds more insoluble than the bone itself.

Commercial grades of bone.

Because bone and tankage are variable, a guarantee should be required. The market has recognized this as fair, and to-day bone is sold and known more by its guarantee rather than by its source. There are a number of grades sold under guarantee of ammonia and bone phosphate of lime instead of nitrogen and phosphoric acid. The quantities of the different grades are becoming less each year, and there is often some variation in the materials

offered on the market. Bone of the following analyses can usually be secured:

GRADES OF BONE

Percentage Ammonia		Percentage Bone Phosphate of Lime		Percentage Nitrogen		Percentage Phosphoric Acid
1½	and	60	equivalent to	1.23	and	27.5
3	and	50	equivalent to	2.47	and	22.9
4 to 4.5	and	45	equivalent to	3.29–3.70	and	19.6
2	and	30	equivalent to	1.65	and	13.75

Bone tankage.

Tankage is made from the residue remaining after boiling cattle heads, feet, clippings, cartilage and other refuse animal matter. It may be classed with boiled bone in reference to the quality of its phosphoric acid. Its agricultural value is further modified by the fineness of division; it is frequently substituted for bone in the manufacture of fertilizers, where phosphate derived from bone is regarded as an important constituent of the mixture or brand.

While the market shows an increased tendency to limit such products, six distinct grades still exist as shown below:

GRADES OF BONE TANKAGE

Percentage Bone Phosphate of Lime		Percentage Phosphoric Acid
18 to 19.0	equivalent to	40
16.0	equivalent to	35
13.5	equivalent to	30
11.5	equivalent to	25
9.0	equivalent to	20
7.0	equivalent to	15

It will be observed that certain grades of tankage approach the composition of bone in their content of phos-

phoric acid; the nitrogen increases as the phosphoric acid decreases, as already pointed out in the discussion of nitrogenous materials.

Other organic products.

There are also other products which should not be disregarded in a discussion of phosphates, though because of their content of either nitrogen or potash they are primarily valued for them, rather than for the phosphoric acid. A good example is the dried ground fish, which often contains as high as 8 per cent of phosphoric acid, or an equivalent of 17 to 18 per cent of bone phosphate of lime. The phosphoric acid in dried fish is frequently more available than in other organic forms, owing to the fact that in the drying of the scrap it is often necessary to add sulfuric acid to prevent putrefaction. On the average, more than one-half of the total phosphoric acid in this product is in an available form.

The phosphoric acid contained in other nitrogenous products, as cotton-seed meal and castor pomace, while not large, is of some importance, as it is relatively more available than in raw bone or in tankage.

Bone-black, or animal charcoal.

This material becomes an important source of phosphoric acid for artificial manures, after it has served its chief and first purpose in clarifying sugar. In making bone-black, only the best bones are used; they are cleaned and dried, and placed in air-tight vessels, and heated until all volatile matter is driven off; the resultant product, which retains in part the original form of the bone, is then ground to a coarse powder; it then becomes a

bone charcoal, consisting chiefly of carbon and phosphate of lime, though also containing small amounts of magnesia and carbonate of lime.

Bone-black, as received from the refineries, contains the impurities gathered there, consisting chiefly of vegetable matter and moisture. It is somewhat variable in composition, containing from 32 to 36 per cent of phosphoric acid and a small amount of nitrogen. It decays slowly in the soil, and is not now used to any extent directly as a manure.

Bone-ash.

Bone-ash is an excellent, though not large, source of phosphoric acid. It is exported in considerable quantities from South America, where the bones are burned and the bulk reduced, in order to facilitate transportation. It does not contain nitrogen, and is more variable in composition than bone-black, though usually somewhat richer in phosphate of lime. Good samples contain from 27 to 36 per cent of phosphoric acid.

Bones themselves, and the phosphates derived from bones, constitute a class differing from other phosphates used in making manures, in that they are derived directly from organic materials and, as a class, they possess characteristics, due to this fact, which render them more useful than those derived from purely mineral sources.

MINERAL PHOSPHATES

These constitute a class of products differing from those of immediate or recent animal origin mainly in the fact that they are not combined with organic matter, and are more dense and compact in their structure. They occur

in several different forms, and are procured from distinct sources.

South Carolina rock phosphates.

These are found both on the land and in the beds of rivers in the vicinity of Charleston, South Carolina, and are sometimes called "Charleston phosphates." The deposits vary in thickness from one to twenty feet, through which the phosphate is distributed in the form of lumps or nodules, ranging in weight from an ounce to over a ton. These nodules are irregular, non-crystalline masses, often full of holes, which contain clay or other non-phosphatic materials. That obtained from the river is called "river phosphate," or "river rock"; and that from the land, "land phosphate," or "land rock." The two varieties do not differ materially in composition, particularly in the content of phosphoric acid.

The rock contains from 26 to 28 per cent of phosphoric acid. Its uniformity, in connection with the fact that it contains but small percentages of compounds of iron and alumina, minerals which prevent its best use by the manufacturer, make it a highly satisfactory source of phosphoric acid.

The river rock is secured by dredging; that from the land is largely dug. In either case it is washed to remove the adhering matter, and then dried, when it is ready for grinding or shipment. South Carolina rock phosphate, when very finely ground, is called "floats." It is sometimes used upon the land in this form, and when used for certain crops, as turnips, for example, and on certain soils, notably those wet and heavy and rich in vegetable matter, very satisfactory returns are obtained.

These deposits were first worked in 1868, though the

presence of phosphate at this point was known at a much earlier date.

Florida phosphates.

The presence of phosphate in commercial quantities in Florida was discovered in 1888, since which time very great progress has been made in developing the deposits. The deposits occur in a number of forms, — first, "soft phosphate," a whitish product, somewhat resembling clay, and largely contaminated with it; second, "pebble phosphate," consisting of hard pebbles, occurring both in river beds and upon the land, and mixed with other materials; and third, "rock," or "bowlder phosphate," which occurs in the form of stony masses or bowlders, both large and small. These three forms also differ widely in composition, both in reference to their content of phosphoric acid and in respect to the presence of other minerals. (See Figs. 3–5, Plates III and IV.)

The soft phosphate is the poorest in phosphoric acid. It is easily prepared, and is largely used directly upon the land. It is also the most variable in composition, ranging from 18 to 30 per cent. The pebble rock is also variable in composition, though, when washed free of sand and clay, it is richer in phosphoric acid than the soft variety. Good samples contain as high as 40 per cent and over of phosphoric acid. The bulk of the "Florida phosphate" is believed to exist in the pebble form.

The rock or bowlder phosphate, though apparently much less in amount, is more uniform in composition, and is much richer than either of the other forms. The clean, dry bowlder phosphate often contains as high as

PLATE III. — Phosphate Mining.

FIG. 3. — PHOSPHATE PIT, DUNNELLON, FLORIDA.

FIG. 4. — MINING PHOSPHATE ROCK BY MEANS OF FLOATING DREDGE.

40 per cent phosphoric acid, far exceeding in richness the South Carolina rock superphosphate.

Canadian apatite.

This material is a crystallized rock of true mineral origin, and occurs associated to a greater or less extent with other materials. It is, therefore, not uniform in character, the phosphoric acid varying according to the amount of the other substances present.

It is mined in the provinces of Quebec and Ontario, and separated into various grades at the mines. The mining is expensive, and the necessity for grading in addition makes the cost of production proportionately high. The highest grade of this phosphate is very pure, containing 40 per cent of phosphoric acid.

Tennessee phosphate.

The phosphate deposits in Tennessee were discovered in November, 1894, since which time they have been exploited and a rapid development made. This phosphate differs from the phosphate of South Carolina and Florida in that it does not exist as nodules, pebbles or bowlders, but in veins and pockets, and, therefore, does not need to be washed and dried previous to its treatment. While the phosphates from the various deposits are not uniform in their composition, it is possible to secure large quantities that equal or exceed 30 to 32 per cent of phosphoric acid, or 70 per cent or over of bone phosphate, and that are relatively free from deleterious substances, thus making them not only a rich but a valuable source of supply for the manufacturers of superphosphates.

Recent discoveries in western states.

The development of the phosphate mines of South Carolina, Florida and Tennessee was so rapid that grave fears were entertained of complete exhaustion. The future prosperity of the agriculture of the United States, however, has been assured by recent discoveries of vast phosphate fields in Idaho, Wyoming and Montana. Estimates of the size of these deposits are much greater than those of the eastern United States already developed and the material is of a distinctly high-grade character.

The conditions surrounding many of these deposits are especially favorable for the manufacture of acid phosphate. Copper smelters are situated not far distant which are capable of producing enormous quantities of sulfuric acid as a by-product, which, as brought out later, is used in large quantities in its manufacture.

Basic-slag.

Thomas phosphate powder, phosphate slag, odorless phosphate, iron phosphate and basic-slag are some of the names given to a waste product found in the manufacture of steel from phosphatic iron ores by a modification of the Bessemer process in which an excess of calcium oxide (lime) is used. It is a heavy, black powder weighing more than any of the more common fertilizer materials, and is extremely fine.

The use of basic-slag is confined largely to the countries manufacturing steel from ores high in phosphorus. It is produced in large quantities in England, France and Germany, and in those countries is not only one of the cheapest sources of phosphoric acid, but is regarded as a very valuable product. The composition varies

with the grade of ore and the amount of lime used in the process of manufacturing steel. The imported product usually contains 15 to 19 per cent of phosphoric acid. Among the chief constituents, other than phosphorus, are a number of compounds containing calcium, magnesium, iron, manganese and silicon. In general the composition will range within the limits following:

Phosphoric acid	12 to 20 per cent
Calcium oxide	35 to 50 per cent
Magnesium oxide	4 to 6 per cent
Manganese oxide	5 to 10 per cent
Iron oxide	12 to 18 per cent
Silica	4 to 8 per cent
Alumina	1 to 3 per cent

The availability of basic-slag is dependent in large measure upon the fineness of division and soil conditions. From 80 to 90 per cent of the total phosphoric acid contained in it is guaranteed available, but experimental evidence shows that the phosphoric acid in basic slag is only a little more than one-half as quickly available as soluble calcium phosphate. The lime contained is undoubtedly an asset. Good results have been obtained on low wet soils, but it is only when the material is used in large quantity that the effects of the lime become noticeable.

Manufactured phosphates.

There are a number of phosphatic materials manufactured in one way or another from minerals bearing phosphorus which are mentioned more as a matter of interest than of practical importance.

Artificial basic-slag meal. — Many attempts have been made to produce by manufacture a material similar to

basic-slag. When apatite or other phosphates are fused with lime and silica, a product is formed which is very similar to basic-slag, known as artificial basic-slag meal.

Wiborgh phosphate. — By fusing feldspar, sodium carbonate and phosphorite at a very high temperature, a product is obtained which contains from 20 to 30 per cent of available phosphoric acid. It has been found to compare very favorably with superphosphates and basic-slag, especially when used upon muck and peat soils. The cost of manufacture is too great to make this material of practical importance.

Wolter phosphate. — This material is manufactured by fusing powdered phosphorite, sodium sulfate, calcium carbonate, sand and coke. When the material is hot it is run into water and finely pulverized after cooling. It compares favorably with basic-slag.

Palmaer phosphate. — This is a high-grade phosphatic material containing 35 to 40 per cent of phosphoric acid in the reverted form, practically all of which is available. It is of especial importance because it affords a means of utilizing mineral apatite. In the process of manufacture apatite is treated with chloric or perchloric acid generated by electricity from sodium salts. It is more effective than basic-slag and compares favorably with superphosphates.

Phosphatic guanos.

Guanos rich in phosphoric acid were for many years previous to the development of the phosphate mines used extensively in this country. The Peruvian guano of earlier times was particularly rich in nitrogen; the purely phosphatic guanos are rich in phosphoric acid, and are excellent materials. Very little of this material

reaches our markets to-day, but an occasional shipment is brought in from the West Indies or islands of the Pacific Ocean.

PHOSPHATES AS SOURCES OF PHOSPHORIC ACID TO PLANTS

The phosphates mentioned constitute what are called "raw materials," and, with the exception of bone, are not largely used directly, or without further treatment to render the phosphoric acid more soluble, and thus more immediately available to plants. As already stated, the phosphoric acid in them becomes food in proportion to the rapidity of decay, which is influenced both by the character of the material and the fineness of its division. Fine materials, too, permit of a more even distribution, thus bringing more particles of phosphate in contact with the roots of plants.

As already stated, a phosphate is a substance in which the phosphoric acid is combined with lime, iron or alumina. The phosphates of lime are the only ones that are used to any extent in the manufacture of artificial fertilizers. The phosphoric acid contained in animal bone is in the form of phosphate of lime, hence the term "bone phosphate of lime" has been applied to all phosphates that contain their phosphoric acid as phosphate of lime. In fact, statements of analysis of iron and alumina phosphates are frequently expressed in terms of phosphate of lime. That is, the content of phosphoric acid is stated as equivalent to a certain percentage of bone phosphate, the term expressing the total amount of combined phosphoric acid; as, for example, a bone which contains 20 per cent of phosphoric acid, which is the average content

in good bone, is equivalent to 43.60 per cent of phosphate of lime.

All phosphates are insoluble in water, but, as phosphates, they are not capable of feeding the plant directly; they must first decay. Hence, the usefulness of a phosphate depends upon the rate of decay, or time required to change to such a form as to become available to the plant. The rapidity with which a phosphate will feed the plant depends upon a number of conditions, chief among which are, first, the character of the substance itself; second, the fineness of its division; third, the character of the soil to which it is applied; and fourth, the kind of crop for which it is used.

The influence of source of phosphate upon availability.

The chief point to be observed in the first case is whether the substance is animal or vegetable, or whether it is mineral. Phosphates of immediate animal or vegetable origin decay more rapidly than purely mineral phosphates, because of the greater tendency of the organic matter with which the phosphate is associated to respond to the action of the natural agencies which cause decay. A bone, for example, if kept in a suitable condition of moisture and warmth, will soon begin to rot, the rotting affecting not only the animal matter, but more or less the phosphatic matter with which it is so closely identified, the fermentation primarily attacking the organic substances, but exercising a greater or less solvent effect upon the phosphates.

In the case of the mineral substances, the rate of decay is usually much slower, because there is no organic fermentation. The material changes or is broken up only by virtue of the action of the natural solvents, air and

water, and solvent substances in the soil. Furthermore, the phosphate of the animal bone is always a phosphate of lime, which, while not soluble, is in itself more readily attacked by the natural agencies than a mineral phosphate which has associated with the bone phosphate other minerals that are not readily attacked by those agencies. That is, the mineral phosphates, while they are made up chiefly of phosphate of lime, are associated with other minerals, as iron and alumina, that are more slowly attacked than the phosphate of lime itself, and to some extent, too, prevent the full effect of the solvents, rather than encourage their action, as is the case with bone.

Influence of fineness of division.

In the second place, fineness of division has an important bearing upon availability, since the finer the substance is ground, the greater will be the surface area exposed to the natural agencies which cause decay. Thus the application of a coarsely ground phosphate may not show any results the first season, while the same substance ground to a powder may have a good effect the first season; that is, its fineness permits of the solubility of a considerable portion of its phosphoric acid.

The character of soil as a factor influencing availability.

In the third place; the kind of soil to which the phosphate is applied may influence the rate at which the plants may obtain it. A soil which is open and porous, and thus permits the free access of air and circulation of water, and one which contains a large portion of other matter capable of decay, vegetable or animal, presents more favorable conditions for the solubility of phosphates

than one which is close and compact in texture and purely mineral in its character, thus preventing the free access of air and water, and in which no organic changes are taking place. In the one case the conditions are such as to favor the action of the natural agencies, and in the other they are such as to retard their action.

Influence of the kind of crop.

In the fourth place, the value or usefulness of phosphates is measured to some extent by the characteristics of the plant or crop to which they are applied. Plants differ in their power of acquiring food. Certain plants are able, because of their peculiar root system, or period of growth, to appropriate food more readily from insoluble sources than others.

General considerations.

All these considerations must be observed in determining the usefulness of a phosphate. It is believed by experienced farmers, though not absolutely confirmed by experimental inquiry, that animal bone, for example, is far superior, as a source of phosphoric acid, for most crops, to the mineral phosphates, though both may be ground to the same degree of fineness; and also, that the finer the bone is ground, the more rapidly will it give up its phosphoric acid.

Laboratory tests show that the phosphoric acid in bone, while insoluble in water, may be partly dissolved at a certain temperature by a neutral solution of ammonium citrate. This medium is used to determine what is called "available" in other phosphatic products. The rate of solubility in this medium is measured by the method of preparation of the bone and its fineness,

the phosphate in raw bone meal of the same fineness showing rather a lower rate of solubility than the phosphates in steamed bone. The phosphate in the finest steamed bone is much more soluble than that in the coarser grades. This measure of the rate of solubility of bone, while not, perhaps, showing the exact rate at which the plants may obtain it, is a fairly safe guide in its use for most crops, as compared with those mineral phosphates which are not perceptibly soluble in this medium. The range of solubility of different kinds and grades of bone is from 20 to 75 per cent, and the average of a large number show about 30 per cent soluble in citrate of ammonia, which would be called "available" if found in mixed fertilizers, and probably can be as safely depended upon as the available shown in other products.

In any case, animal bone, or finely ground mineral phosphates, cannot be depended upon to meet fully the needs of quick-growing crops for phosphoric acid, but may answer an excellent purpose where the object is to improve gradually the soil in its content of this constituent, as well as to supply such crops as are continuous, or that grow through long periods, as, for example, meadows, pastures and orchard and vineyard crops.

As to the specific substance, the iron phosphate, or Thomas phosphate powder, experiments in Europe have shown that it possesses a higher rate of availability than other phosphates which are insoluble in water, but which show the same rate of solubility in ammonium citrate, though its solubility, or availability, is measured to some extent by the degree of fineness to which it is ground; and it is believed that its special form, the tetra-calcic, also exercises a considerable influence upon the rate of availability.

European vegetation and field experiments show pretty clearly that two parts of phosphoric acid from the Thomas phosphate powder are approximately equivalent to one part from soluble phosphoric acid, and that this phosphate is especially useful on wet, marshy soils and those poor in lime. Experiments conducted in this country practically confirm these conclusions.

The relative availability of the phosphates in the natural guanos has also been shown to be somewhat higher than in other insoluble phosphates. These latter substances for this reason possess a distinct value over others for certain classes of crops, as, for example, cranberries, where the soluble phosphates would be liable to be washed out, and where the organic phosphates would be liable to float on the surface of the water, and also where lands are cold and sour, and not readily fermentable.

The practical point, however, to the farmer is the amount of increase that he may obtain from a certain definite expenditure, a matter which will be discussed later, in the discussion of the use of fertilizers for the various crops.

CHAPTER V

SUPERPHOSPHATES — POTASH

THE different phosphates mentioned in the previous chapter constitute the sources of supply for the manufacture of commercial fertilizers. That is, with the exception of animal bone, Thomas phosphate powder and natural guanos, they are used more extensively for this purpose than directly on the land in their raw state. They are the raw materials from which the manufactured phosphatic fertilizers are derived. The purpose of the manufacture is to convert them into a form in which the phosphoric acid is immediately available, and thus directly useful to the plant. The term "available" in this case is used in the same sense as in the discussion of the forms of nitrogen (Chapter III), and it means that when the phosphoric acid is in this form, the plants may acquire it immediately.

INSOLUBLE PHOSPHORIC ACID

Phosphate of lime is, chemically speaking, a salt capable of existing in various forms, the form measuring in large degree the rate of availability. The phosphate of lime, as it exists in the animal bone and mineral phosphates, for example, consists of three parts of lime and one of phosphoric acid. This is the insoluble form. It is not immediately available, and because of the three parts of

lime to one of phosphoric acid, which it contains, it is also called tricalcic, tribasic or bone phosphate, and is graphically expressed in this formula:

Lime	
Lime	Phosphoric Acid
Lime	

That is, in each molecule, however small, there are three parts of lime and one part of phosphoric acid.

SOLUBLE PHOSPHORIC ACID

In another form, the phosphate consists of one part of lime and one of phosphoric acid, two parts of the lime in the tricalcic form being replaced with water. This form is called monobasic, or monocalcic. It is a saturated phosphate. There could be no less than one part of lime to one of phosphoric acid, and such phosphates are called acid phosphates, or superphosphates. The combination of the lime and phosphoric acid may be shown as follows:

Lime	
Water	Phosphoric Acid
Water	

This form is completely soluble in water and immediately available, and when applied to the soil readily distributes itself everywhere, thus making it more useful than any other form.

REVERTED PHOSPHORIC ACID

Another form of phosphate consists of two parts of lime and one part of phosphoric acid, and is called dicalcic,

dibasic or reverted. One part of the lime in the insoluble is replaced by an equivalent of water, and is expressed as follows:

Lime Lime Water	Phosphoric Acid

The reverted form, which means a going back from the soluble toward the insoluble form, is also insoluble in water, but is readily soluble to the roots of plants.

It was formerly supposed that these three were the only forms in which phosphoric acid existed, but another form, in which four parts of lime are combined with one of phosphoric acid, and thus called tetrabasic, or tetracalcic, has been found quite recently to exist in the Thomas phosphate powder:

Lime Lime Lime Lime	Phosphoric Acid

This form is insoluble in water, though it has been found to be more available than the insoluble tribasic form.

HOW SUPERPHOSPHATES ARE MADE

Any material which contains a high content of the tricalcic or bone phosphate, 60 per cent or over, is suitable for the manufacture of superphosphates, provided it does not possess a too high content of deleterious substances. In the manufacture of superphosphates, the phosphate is first ground to a fine powder, then mixed with sulfuric acid. The acid dissolves the phosphate, and two parts of the lime which are combined with the phosphoric acid in the tricalcic form are first set free, and then combined with the

sulfuric acid, making a superphosphate (monocalcic), and a sulfate of lime or gypsum. That is, in this process, two of the three parts of the lime combined with the phosphoric acid to form the insoluble phosphoric acid, are removed, thus leaving one part of the lime combined with the phosphoric acid, making the superphosphate. A pure superphosphate is, therefore, a mixture of soluble phosphate and of sulfate of lime or gypsum.

The difference in the superphosphates made from the different materials.

In the early use of superphosphates, the chief raw material was animal bone. The superiority of the bone superphosphate, or dissolved bone, as it was called, over the raw bone was manifest at once, and the familiarity with genuine bone superphosphates thus early acquired by farmers was, perhaps, quite as influential as any other in creating a prejudice in favor of their continued use in preference to superphosphates derived from mineral phosphates. The opinion that the bone superphosphate is "the best" is held even at the present day, notwithstanding the equally satisfactory results that have been obtained from the use of the superphosphates from other sources.

Soluble phosphoric acid chemically identical, from whatever source derived.

Chemically speaking, the soluble phosphoric acid produced by the action of sulfuric acid upon mineral phosphates is identical with the soluble phosphoric acid derived from animal bone, and if the soluble from each could be separated from the other substances with which they are associated, there would be no difference whatever in the results of their use. They are identical; just as much so as am-

monia obtained in the manufacture of bone-black from bones is identical with the ammonia obtained in the manufacture of illuminating gas or coke. In many cases, doubtless, superior results have been obtained from the use of the animal bone superphosphate, though this has not been due to any inferiority of the available phosphoric acid in the mineral superphosphate, but rather to the fact that substances have been compared that are not strictly comparable. They are radically different. The one contains, in addition to its available phosphoric acid, the only fertilizing ingredient in the mineral superphosphate, considerable nitrogen, and, moreover, it contains its insoluble phosphoric acid in a form that is liable to decay more rapidly than the insoluble in the mineral phosphate. Soluble phosphoric acid is a definite compound. The source from which it is derived does not influence this point, and the action of a definite quantity is also identical when conditions are similar.

PHOSPHATES AND SUPERPHOSPHATES ARE NOT IDENTICAL

The idea in the term "phosphate" should also be kept distinct from that conveyed by the term "superphosphate." The first means, and should be applied to, any material containing as its chief constituent phosphoric acid; the other means, and should be applied to, any material containing soluble phosphoric acid as its chief constitutent. The phosphates which have already been described are each capable of being converted into a superphosphate, as animal bone superphosphate, South Carolina rock superphosphate, bone-black superphosphate, bone-ash superphosphate, Florida rock superphosphate, and Tennessee rock superphosphate. These superphos-

phates vary in their content of soluble phosphoric acid, due both to the variation in the content of the phosphoric acid in the phosphates used as raw materials, and to the excellence of the method of manufacture. In other words, the superphosphates, while practically identical in so far as the form of phosphoric acid is concerned, vary in their total content of soluble phosphoric acid. For example, superphosphates made from the animal phosphates, as bone-black, bone-ash and the like, are usually richer in soluble phosphoric acid than those made from animal bone, or from many of the mineral phosphates, because these phosphates are of such a character as to enable the manufacturer to convert all the phosphoric acid present into a soluble form, and at the same time to secure a fine, dry product, that may be readily handled — an important consideration in making superphosphates.

Mineral phosphates, both because of their hardness and of the presence of other minerals, which are attacked by the acid, are less easily dissolved, and require more acid in proportion to the phosphate present than those from organic sources. They are also less absorbent, preventing the acid from permeating the mass of the material, and hence it is more difficult to secure good condition when sufficient acid is used to dissolve the phosphate. In making superphosphates from these materials, less acid is used than is required to completely dissolve the phosphates, and there is, therefore, always present in them more or less of the insoluble phosphoric acid.

In the case of animal bone, too, less sulfuric acid is used than is required to completely dissolve the phosphoric acid. Otherwise, a gummy, sticky product would result, due largely to the organic matter in the bone. The insoluble phosphoric acid in bone, bone-black and bone-ash

superphosphates is, however, of greater value than the insoluble in the mineral phosphates, for reasons already given.

In superphosphates, also, there is nearly always present a greater or less amount — depending upon the material — of the second form of phosphoric acid, the dicalcic, reverted or retrograde. This form usually exists in the greatest amounts in those made from mineral phosphates, which is believed to be due either to the soluble acting upon the insoluble portions, or to the presence of oxide of iron and alumina, which combine with a portion of the soluble phosphoric acid. The soluble goes back to the less soluble dicalcic form.

Aikman states the matter very clearly in the following words:[1] "A change which is apt to take place in superphosphate after its manufacture is what is known as 'reversion of the soluble phosphate.' Thus it is found that on keeping superphosphate for a long time the percentage of soluble phosphate becomes less than it was at first. The rate at which this deterioration of the superphosphate goes on varies in different samples. In a well-made article, it is practically inappreciable, whereas in some superphosphates, made from unsuitable materials, it may form a considerable percentage. The causes of this reversion are two-fold. For one thing, the presence of undecomposed phosphate of lime may cause it. This source of reversion, however, is very much less important than the other, which is the presence of iron and alumina in the raw material. When a soluble phosphate reverts, what takes place is the conversion of the monocalcic phosphate into the dicalcic.

"Where reversion is due to the presence of iron and

[1] "Manures and Manuring."

alumina in the raw material, the nature of the reaction is not well understood, and is, consequently, not so easily demonstrated as in the former case. Where iron is present in the form of pyrites, or ferrous silicate, it does not seem to cause reversion. It is only when it is present in the form of oxide (and in most raw phosphatic materials it is generally in this form) that it causes reversion in the phosphate."

Aikman also discusses the value of reverted phosphates, showing the estimation in which they are held in England: "The value of reverted phosphate is a subject which has given rise to much dispute among chemists. That it has a higher value than the ordinary insoluble phosphate is now admitted, but in this country, in the manure trade, this is not as yet recognized. At first it was thought that it was impossible to estimate its quantity by chemical analysis. This difficulty, however, has been overcome, and it is generally admitted that the ammonium citrate process furnishes an accurate means of determining its amount. Both on the continent and in the United States reverted phosphate is recognized as possessing a monetary value in excess of that possessed by the ordinary insoluble phosphates. The result is, that raw mineral phosphates containing iron and alumina to any appreciable extent are not used in this country, although they do find a limited application in America and on the continent."

As stated by Aikman, the reverted phosphoric acid due to the presence of undecomposed phosphate, as well as the reverted due to the presence of iron and alumina, are recognized by the chemists in this country, and this recognition is strongly encouraged by commercial interests, because of the fact that our mineral phosphates contain, as a rule, iron and alumina, which by their action reduce

the percentage of the soluble. The method of chemical analysis which has been adopted by the American Association of Official Agricultural Chemists recognizes this form, and it is, therefore, determined and included in the "total available" in statements of analysis. In one state, New Jersey, the law requires that the dicalcic form only shall be recognized, and it assumes that the agricultural value of this form is equal to that of the soluble.

DOUBLE SUPERPHOSPHATES

In addition to the superphosphates made directly from the various materials mentioned, a special substance, called a "double superphosphate," which may be made by dissolving low-grade phosphates with an excess of dilute sulfuric acid, or those too poor in phosphoric acid to make a high-grade superphosphate. The dissolved phosphoric acid thus obtained, together with the excess of sulfuric acid, are separated from the insoluble materials by filtering, which acids, after concentration, are then used for dissolving the better phosphates; and because the acids used for dissolving the phosphates contain phosphoric acid, the content of available phosphoric acid in these products is more than double that contained in the ordinary products. These are mostly manufactured in Europe, and are not used to any extent in this country. They possess the advantage of containing a minimum of impurities and a maximum of phosphoric acid in a soluble form.

In stating the composition of superphosphates, the three forms of phosphoric acid are all recognized. The sum of the soluble and reverted forms is called the "total available," because these, as already stated, are regarded as immediately useful to the plant. In commercial trans-

actions in mineral superphosphates, the total available only is regarded, — the content of insoluble being ignored.

CHEMICAL COMPOSITION OF SUPERPHOSPHATES

As already stated, the composition of the superphosphates varies according to the richness in phosphoric acid of the phosphates used, and according to the character of the material. Bone-ash and bone-black superphosphates are more uniform in composition than those derived from the mineral phosphates, and the phosphoric acid is practically all in the soluble form. They contain on the average about 16 per cent of total available phosphoric acid. The mineral or rock superphosphates differ from these in being more variable in their total content of available, and in showing wider variations in the proportions of reverted, the latter depending upon the skill in manufacture, as well as the character of the original material. Well-made South Carolina rock superphosphates contain from 12 to 14 per cent of total available, of which 1 to 3 per cent is dicalcic, or reverted. There are several grades of the Florida rock superphosphates, due to the variation in the composition of the various raw phosphates. The pebble superphosphates are the richest, often containing as high as 16 or 17 per cent of total available, with varying percentages of reverted and insoluble. The Tennessee superphosphates also vary from the same cause, the richest showing as high as 16 to 18 per cent of total available. The concentrated, or double, superphosphates may contain as high as 45 per cent of available, practically all of which is soluble. The superphosphates made from animal bone are usually more variable in their composition than those

from bone-black, bone-ash or mineral phosphates, and the variation is due both to the variability of the raw materials and the difficulties involved in their change into superphosphates. The usual guarantee on an animal bone superphosphate is 12 per cent available, and from 3 to 5 per cent of insoluble. These superphosphates also differ from the mineral superphosphates in containing nitrogen in addition to their phosphoric acid. They are, therefore, really ammoniated superphosphates.

Well-made superphosphates contain no free acid.

In the earlier history of the use of acid phosphates, or rock superphosphates, objections were urged against them, and are to some extent at the present time, because of the supposed deleterious effects of the acids contained in them, and these objections were undoubtedly encouraged, — certainly not discouraged, — by those manufacturers who used only genuine bone superphosphates. While the objections on this ground may have had some basis in earlier times, before their manufacture was well understood, there can be no rational objection to their use at the present time, when they are properly made; for while in fresh superphosphates a portion of the phosphoric acid may be in the form of "free" phosphoric acid, this form in ordinary superphosphates is practically all combined with lime or other minerals before it is placed upon the market, and there is really no more "free" acid in the rock superphosphate than in any other. It is quite likely this erroneous impression arose from the fact that strong sulfuric acid was used in the manufacture, and the belief existed that it remained as such. No free sulfuric acid exists in well-made superphosphates. The sulfuric acid is combined with the lime to form gypsum, as already de-

scribed, and the free phosphoric acid combines with the lime to form either a soluble or a reverted form.

Phosphoric acid remains in the soil until taken out by plants.

The phosphoric acid in superphosphates, though soluble in water, is not readily washed from the soil. The real object of making it soluble is to enable its better distribution. If it were possible to as cheaply prepare the dicalcic or reverted form as the soluble, it would, perhaps, be quite as useful from the standpoint of availability. After the soluble is distributed in the soil, it is fixed there by combining with the lime and other minerals present. It is believed that it assumes, first, by the larger relative proportion of lime usually present in soils, the dicalcic form, though it is not positively certain that in the present of an abundance of lime, or that in time, it may not assume the insoluble tricalcic form. The soluble phosphoric acid may also combine with the iron and alumina in the soil, and form phosphates of these elements, though recent investigations lead to the conclusion that these conditions are much more rare than was at one time supposed. The time required for the fixing of the phosphoric acid, as well as the form it may eventually assume, depends chiefly upon the character and composition of the soil. In those rich in lime, the fixation is most rapid, though in no sense is the fixation immediate, and in such soils the fixation is probably largely completed in the course of a week. On clay soils, containing a low percentage of lime, and in light soils that contain little clay or organic matter, the fixation is much slower, though even in these the chances are that no serious loss of phosphoric acid occurs. Seldom do we find more than traces of phosphoric acid in drainage waters, even when heavy applications of soluble phosphoric acid

are followed by heavy rains. The fact that the fixing power of soils practically prevents the loss of phosphoric acid should, however, not be used as an argument in favor of the careless use of superphosphates.

POTASH SALTS

Until the discovery of the mines of crude potash salts in Stassfurt, Germany, in 1859, and which have been worked since 1862, the chief source of potash for farm plants, other than that contained in farmyard manures, was wood-ashes. The supply from this source now, however, is sufficient to meet all immediate as well as future demands, since the deposits are practically inexhaustible, though notwithstanding the abundance of the supply and the improvements made in the methods of utilizing the various salts, other than potash, contained in the deposits, it is the only fertilizer constituent which has remained practically constant in price during the past fifteen years. In this period not only have wide fluctuations occurred in prices of nitrogen and phosphoric acid from the different sources, but they are much lower now than formerly.

The importance of potash as a constituent of fertilizers.

It has been attested that potash is of relatively less importance than either nitrogen or phosphoric acid, inasmuch as good soils are naturally richer in this element, and because a less amount is removed in general farming than of either nitrogen or phosphoric acid, as the potash is located to a less extent in the grain than in the straw, which is retained upon the farm. It is, however, a very necessary constituent of fertilizers, being absolutely essential for those intended for light, sandy soils and for peaty

meadow lands, as well as for certain potash-consuming crops, as potatoes, tobacco and roots, since these soils are very deficient in this element, and the plants mentioned require it in larger proportion than do others. In fact, it is believed by many careful observers — and the belief has been substantiated in large part by experiments already conducted — that the average commercial fertilizer does not contain a sufficient amount of this element. It is a particularly useful constituent element in the building up of worn-out soils, because contributing materially to the growth of the nitrogen-gathering legumes, an important crop for this particular purpose.

Forms of potash.

Potash, as has already been stated in the discussion of phosphoric acid and nitrogen, exists in various forms, but it differs from the other elements in that its chemical form or combination seems to exert but relatively little influence upon the availability of the constituent. For example, it may be in the form of a muriate or chlorid, of a sulfate or of a carbonate, and while there is a difference in the diffusibility of these different compounds, — that is, a difference in the rate at which they will distribute in the soil before becoming fixed, — there seems to be very little difference in the rate of the absorption of the potash by the plant. Nevertheless, the form of potash must be observed, because of the possible influence that the substances with which it combines may exert in reducing the marketable quality of the crop to which it is applied. This influence has been very distinctly observed, particularly in the growing of tobacco, sugar-beets and potatoes, and it has been shown that the potash in the form of a chlorid (or muriate) does exert a very deleterious effect, especially

on tobacco. In fact, tobacco manures should not contain potash in the form of a muriate. For such crops as the various clovers, Indian corn (maize) and the various grasses, no particular difference has been observed, and the form of potash that may be procured at the lowest price per pound of the constituent is the one, other things being equal, to use for these crops.

Kainit.

In the next place, the potash salts that may be obtained are divided into two classes: first, the crude products of the mines, and second, the manufactured products. Of the crude products, kainit is the one more largely used in this country than any other. The potash contained in it is practically all in the form of muriate or chlorid. It is a compound of chlorid of potassium and sulfate of magnesium associated with about 30 per cent of common rock salt or sodium chlorid. It is really a mixture varying in composition according to the mines from which it is obtained. It is generally sold in its natural state for fertilizer purposes, although a large part of the output of true kainit is used in the manufacture of sulfate of potash. The commercial product is guaranteed to contain 12 per cent of actual potash. Because of its low content of potash as compared with the manufactured products, the cost of the actual potash is usually greater than in these, owing to the increased cost of shipping and handling per unit of potash. It is more generally used near the sources of supply, rather than at a distance, unless the substances, as ordinary salt, also exert a beneficial indirect influence upon the soil, as is very frequently the case. It is not advisable to apply it immediately preceding the planting, nor in the hill or row, because of the danger to the young plant from

the excess of both the chlorids of sodium and magnesium, which are injurious to the tender rootlets. Where its use is intended to benefit the immediate crop, it should be applied a considerable time before the crop is planted, in order that it may be well distributed, and that a portion of the chlorids, which are extremely soluble, may be washed into the lower layers, or into the drains.

Hardsalt.

This is another crude potash salt which is imported for fertilizer purposes. Its composition is very much like kainit except that it contains more water in combination. It is a mixture of chlorid of potassium, sulfate of magnesium and chlorid of sodium. The commercial product sold in the United States is guaranteed to contain 16 per cent of actual potash. Its use as a fertilizer is the same as that of kainit.

Carnallit.

Carnallit is of practical importance as a fertilizer only in localities not far distant from the mines and is mentioned because it is the chief source of muriate of potash and other concentrated potash salts. It is really a double compound of muriate of potash and magnesium chlorid and has associated with it large quantities of common rock salt and kieserit, which is sulfate of magnesia, and other minerals. It contains about 9 per cent of actual potash and has the property of absorbing large quantities of water.

Muriate of potash.

Of the more concentrated potash salts, muriate of potash manufactured from carnallit is by far the most common

and most generally used. It varies somewhat in composition, according to the method of manufacture, though practically only three grades are met with in this country and only one of these is used to any great extent for agricultural purposes. These grades are:

Basis 98 per cent pure . .	contains 61.9 per cent actual potash
Basis 95 per cent pure . .	contains 60.0 per cent actual potash
Basis 80 per cent pure . .	contains 50.5 per cent actual potash

The last grade is most common, and because it absorbs moisture is guaranteed to contain 48 per cent actual potash, though the absorption of water makes little difference because it occurs after the material is placed in the bag and hence the correct amount is contained even if it is slightly diluted. The chief impurities of muriate of potash (chlorid) are common salt, or sodium chlorid, and insoluble matter, which are not deleterious substances. The lower the content of potash, the higher the content of impurities, though in all cases this form of potash is sold upon the basis of 80 per cent muriate.

High-grade sulfate of potash.

High-grade sulfate of potash is manufactured and used in much smaller quantities than muriate. It is made from muriate and kieserit at the present time, though formerly was manufactured exclusively from kainit. The commercial product contains from 47 to 52.7 per cent of actual potash, or about 90 to 96 per cent of pure sulfate of potash, though the most common grade contains 48 per cent of actual potash. It naturally varies somewhat in its composition, owing to impurities, either introduced or imperfectly removed. It is, however, regarded as preferable to the muriate for some crops, for reasons already

given (page 94), in spite of its slightly greater cost. It is rather less diffusible than the muriate, though it is not inferior to it as a source of actual potash.

Double manure salt.

Double manure salt, or double sulfate of potash and magnesia, is a product obtained by refining kainit by recrystallization. Though it contains less potash, it is similar in its effects to the high-grade sulfate of potash, because it contains no chlorids, and is free from other deleterious substances. In many cases the 25 per cent of sulfate of magnesium with which it is associated is believed to be of considerable service. The potash contained in it is equivalent to 25 to 26 per cent actual potash. The cost of potash in this material is greater than in the muriate.

Potash manure salt.

Potash manure salt is a term used to designate a low-grade muriate of potash containing 20 per cent of actual potash. It may be employed in a manner similar to the use of muriate of potash. It must be remembered, however, that the potash contained is in the form of a chlorid, and that other impurities including sulfate and chlorid of magnesium, common salt and a few other compounds are associated with it.

Double carbonate of potash and magnesia.

This material imported from Germany is a finely divided powder containing about 20 per cent of potash and an equal amount of magnesia free from chlorids. On account of the small amount brought to this country it is relatively unimportant.

PLATE IV. — Mining and Composting.

FIG. 5. — MINING PHOSPHATE ROCK BY HYDRAULIC PRESSURE.

FIG. 7. — UNLOADING AND COMPOSTING NEW YORK STABLE MANURE IN SOUTH JERSEY.

Potassium carbonate.

Potassium carbonate is used to some extent as a fertilizer and sometimes upon compost heaps. Investigations show that it is well adapted to tobacco-growing. It is a high-grade product containing 65 per cent of actual potash.

Potassium nitrate.

This material already mentioned would be especially valuable for agricultural purposes were it not for its greater value for use in the manufacture of gunpowder and explosives which makes it more expensive than the combined cost of the separate ingredients in other salts. It is also called nitrate of potash, niter and saltpeter, and contains 14 per cent of nitrogen and 44 per cent of actual potash.

Feldspar and other minerals as a source of potash.

Feldspar and a large number of other minerals including leucite, alunite, phonolite and nepheline have caused much thought and experimentation upon the part of chemists and investigators for a number of years as probable sources of potash. So far, little of practical importance has been accomplished with these minerals because no methods have been developed which would successfully extract the potash, and pulverization even to extreme fineness does not render potash contained in them available.

Formations of alunite recently found at Marysvale, Utah, caused considerable comment at the time of their discovery; but, here again, the manufacture is still in the experimental stage. Nor has leucite, which contains 18 to 20 per cent of actual potash, been found practicable.

Seaweeds as a source of potash.

The flora of the Pacific Ocean includes many different kinds of giant seaweeds which grow luxuriantly in the coast waters from Alaska to Mexico. The giant kelp groves have attracted much attention as a source of potash. The ash of these weeds contains often as high as 30 per cent actual potash. Great possibilities are presented by these vast groves of seaweed because they may be harvested periodically and continue productive. Up to date, however, no practical method has been developed which enables the harvest and preparations for market of this material at a cost sufficiently low to compete with the German products.

Fixation of potash.

Potash, like phosphoric acid, is readily fixed in the soil, though the chlorids with which it is combined when applied may form soluble compounds that are readily leached from the soil. For example, the chlorin combined with the muriate may be combined with lime or soda, forming soluble chlorids of lime or soda; hence, heavy applications of muriate of potash may result in the exhaustion of lime in the soil. The fact that the potash is fixed, and that the chlorids remain soluble, enables the application of a large quantity, which might otherwise be injurious. That is, if muriate, of potash is applied a considerable time before the crop that may be injured by excess of chlorids is planted, the chlorids are washed out, while the potash remains.

Another point of importance should be observed in this connection: the rapidity of fixation on many soils, especially those of an alluvial character, which explains the recommendations frequently made to apply potash salts

broadcast and immediately cultivate in, otherwise the fixation would take place at points of contact, and the distribution be incomplete.

While it is true that potash salts readily become fixed in soils, it is also true that on light, sandy soils, which are greatly deficient in silt, clay and vegetable matter, they may be subject to moderate leaching and slight loss into the drainage water. Where irrigation is practiced on such soils the probability of such leaching is even greater. In either case caution should be exercised in their use.

CHAPTER VI

MISCELLANEOUS FERTILIZING MATERIALS

In addition to the specific fertilizer materials described in the previous chapters, which constitute the standard sources of supply, a number of other products exist, and should be considered here. Certain of these may serve in the manufacture of fertilizers, and certain others, which are not suitable for this purpose, may be used to advantage either because they furnish the constituents in considerable quantities, or in other ways assist in improving the fertility of the soil. They are often a cheap source of nitrogen, phosphoric acid or potash, besides contributing toward "condition" of soil, which exercises a decided influence in making possible the best use of commercial fertilizers.

Furthermore, while a consideration of these products may not be regarded as strictly pertaining to the subject of commercial fertilizers, a discussion of them is valuable, in order that certain impressions now existing concerning them may be corrected. These impressions, while not entirely erroneous, are not wholly in accord with scientific facts, particularly as to how far they may be substituted for the better products; and on this point information as full and exact should be had as the limited knowledge that we have of the subject will permit. These various products cannot be strictly classified into the three main groups: nitrogenous, phosphatic and potassic. They are, as a rule,

rather general in their effect; they contain small amounts of all the essential constituents rather than large amounts of one or two, and many of them are useful, because of their indirect action.

Tobacco stems and stalks.

Tobacco stems consist of the waste stems or ribs of the leaves, and parts of the leaves themselves, which result from the stripping of tobacco for the manufacture of cigars, or for smoking and chewing tobacco. The stalks include the main stem and branches of the plant. The stems are frequently ground and sold as a fertilizer, and the product is valuable for its nitrogen and potash — the nitrogen ranging in content from 2 to 3 per cent and the potash from 6 to 10 per cent. They contain but small amounts of phosphoric acid. The nitrogen exists in both the nitrate and organic forms. The nitrate form constitutes from one-third to one-half of the total nitrogen, and its presence is due both to the fact that nitrogen exists as such in the tobacco plant, and to the fact that saltpeter (nitrate of potash) is frequently added in order to improve the marketable quality of the lower grades of tobacco. The potash occurs largely in the soluble form, and is free from chlorids. The tobacco stalks are somewhat richer in nitrogen than the stems, ranging from 3 to 4 per cent, and are poorer in potash — about 4 to 5 per cent of potash — though the forms of these two constituents are similar in the case of both to those contained in the stems. Both stems and stalks may be frequently obtained in the vicinity of towns where tobacco manufacture is carried on, and while more variable in their content of nitrogen and potash than the ground stems and stalks, due largely to the variations in the content of moisture, they are a

useful and often a very cheap source of nitrogen and potash.

These waste tobacco products are free from deleterious compounds, and for this reason alone are highly valued as a fertilizer for tobacco, as well as for small fruits, for which they are especially useful, because of their known insecticidal value. A ton of tobacco stems of good quality contains nitrogen equivalent to the amount contained in 500 pounds of nitrate of soda, and potash equivalent to the amount contained in 200 pounds of high-grade sulfate of potash. They, therefore, possess a distinct value as a source of these constituents.

Tobacco salts.

Extracts of tobacco are becoming important for insecticidal purposes. In the manufacture of these extracts there are a number of by-products produced which are sold for fertilizer purposes. Various names have been used to designate these products. The most common are tobacco ammonia salt and tobacco potash salt. The former contains about 14 per cent of nitrogen and 6 per cent of potash; the latter 1 to 2 per cent of nitrogen and about 40 per cent of potash. In localities where this industry is extensive, these salts are of more than ordinary interest because the plant-food contained in them is in highly available forms. The nitrogen is in the form of nitrate and ammonia, and the potash is the form of sulfate free from chlorid.

Crude fish scrap.

It frequently happens that farmers are so situated as to be able to procure directly from the fishermen the fish scrap from which dried ground fish is made. Very large

amounts are used in this crude form in our coast states, particularly New England and the middle states. This material, while chiefly valuable for its nitrogen, is not uniform in its content of fertilizing contituents, owing to the wide variation in the content of moisture, or water, which may range from as low as 25 to as high as 75 per cent. The nitrogen, of course, varies with the dry matter, and ranges from 2.5 to 8 per cent. The scrap also contains considerable amounts of phosphoric acid, ranging from 2 to 6 per cent. The fish scrap in this form, too, is less valuable as a source of nitrogen than the dried ground material, because of its coarser condition, requiring a longer time for decay.

The whole fishes (menhaden) are also used either directly or in a composted form in many instances, and the excellent results obtained are mainly due to the rapidity of decay of the nitrogenous substances. The economical purchase of these products depends largely upon the judgment of the farmer. He should be guided in determining their value by the amount of water contained in them. As they approach dryness, they become richer in the constituents of fertility. In any case, products of this sort should be obtained at so low a price per ton as to guarantee to the purchaser a maximum quantity of the fertilizing constituents for his money, when measured by the market value of the materials of known composition.

For example, if crude fish scrap, which contains as a minimum 2.5 per cent of nitrogen, can be purchased for $5 a ton, it will furnish nitrogen at 10 cents a pound, or at two-thirds the cost of this element in nitrate of soda at $48 a ton. Besides, the scrap contains phosphoric acid in good forms. At this price, the purchaser could afford to take the risk incident to the variability of the product.

Wool and hair waste.

Wool and hair waste have already been described in part, though more largely from the manufacturers' standpoint, as representing materials that may be utilized in the manufacture of commercial fertilizers. These products may frequently be obtained in large quantities and at a low price per ton in towns in which the original products are used in manufacturing, and thus occur as wastes. Both are extremely variable in their composition, the wool, particularly, being very liable to change in this respect, owing both to the admixture of non-nitrogenous substances, such as cotton, and to the source of the waste itself, whether it consists of the clippings and tags from the original fleece, or whether it is in part the manufactured product. Different samples show a wide range in the content of nitrogen and potash, from 2 to 10 per cent in the former, and from 1 to 3 per cent in the latter. The nitrogen in the waste is extremely slow in its action in the soil, though it may be made directly useful, both as an absorbent of other wastes, as in liquid manure, and as an ingredient of composts. Excessive quantities must be applied in order to obtain a marked immediate result.

The hair waste is also variable, both on account of the content of moisture, as well as the admixture with it of other substances.

Lime often occurs as a waste product in some industries, and as such it is frequently wet and pasty, and not easily handled.

These wastes, when they can be purchased at a low price a ton, — and frequently they may be obtained as low as two or three dollars, — serve an excellent purpose as absorbents, and for use in orchards and pastures, or in gradually building up the fertility of poor soils.

Sewage.

In recent years, great progress has been made in the handling of sewage from cities, and there is now a product called "sewage sludge," which is obtained in many towns, as a result of its chemical treatment. Such examinations as have been made of this product show it to be very poor in the fertilizing constituents, showing less than .20 per cent nitrogen, .05 phosphoric acid and .05 potash. It is seldom worth the handling. The untreated sewage and garbage wastes are also obtainable in large quantities, and while the constituents contained in them act quickly, and while they are considerably richer in these than the sludge wastes, it seldom pays the farmer to handle them, owing to their offensive character and the enormous amount of useless moisture contained in them.

A number of state institutions, sanatariums, prisons, reform schools and the like which maintain a large number of persons and farms run in connection with the institution have not only installed separate sewage systems, but they have also equipped these systems in a manner which permits the use of the sewage as a part of irrigation systems. This practice of utilizing sewage has proved very successful in a number of instances, but the liquid should not be used as freely as water and care should be exercised in its application.

Muck and peat.

On many farms there are low, wet places, where the conditions are favorable for the collection of partially decayed vegetable matter. The material thus formed is called muck or peat. The thickness of the deposit, and its character, depend upon the time during which it has been formed, and the character of the climate.

Muck is used mainly as a source of humus, and serves an excellent purpose as an absorbent in cattle stalls or yards. Fresh muck, while varying in composition according to its source, may be said to contain on the average 75 per cent of water and about .75 per cent of nitrogen, and only traces of potash, phosphoric acid and lime. Air-dry muck also varies in composition, largely owing to the different proportions of vegetable and mineral matter contained in the different products, as well as the amount of water absorbed in its dry state. The richer it is in vegetable dry matter, the richer in nitrogen. The value of the muck as a source of humus is measured by its content of nitrogen, while its value as an absorbent depends upon its content of organic matter. It should also be remembered that it is generally very acid in character. Analyses show its lime requirement to be as high as four tons calcium oxide to the acre-foot, hence its use presupposes the addition of acid to the soil and the necessity for lime to correct this condition. The value of muck for either of these purposes is further modified by the labor necessary to secure it in a dried condition. This product is of doubtful value as a source of immediately available nitrogen.

The usual method of securing it is to throw it out of the bed into heaps, and allow it to dry before it is used, either upon the field or in the stables. Where a muck bed exists upon a farm, it should first be studied in reference to its possible drainage. If it can be drained, it is liable to prove more useful where it lies than for the other purposes mentioned.

At the present time, muck is air-dried, bagged and placed upon the market as "humus." It is very doubtful whether material of this character can justly be termed "humus"

because the amount of acid contained in it is great and because it is in a state of slow decomposition. It is not uncommon to fortify it with different proportions of fertilizer materials such as nitrate of soda, acid phosphate, muriate of potash and the like. Whatever the process of manufacture, muck or humus seldom contains the fertility elements in sufficient quantity or proper form to warrant its purchase unless the price is low and compares favorably with the price of city manure.

King crab, mussels and lobster shells.

King crab is found in considerable quantities along the Atlantic coast, and is not only used directly as a fertilizer, but is also dried and ground and introduced into commercial mixtures. It is a highly nitrogenous product, containing in the dry state an average of 10 per cent, with traces only of phosphoric acid. It also possesses a high rate of availability, though information on this point is derived from the practical experience of farmers, rather than from actual scientific test. It is also used in many sections of New Jersey in its green or fresh state, either directly on the land or in the form of a compost, and because of its nitrogenous character, and its tendency to decay rapidly, is a valuable source of this element, of which, in its fresh state, it contains from 2 to 2.5 per cent.

In certain sections of the coast states farmers have access to an almost unlimited supply of mussels, which may be had for the carting. Analyses made at the New Jersey Experiment Station show them to contain, in their natural state, a very considerable amount of fertilizing constituents, the nitrogen reaching .90 per cent, the phosphoric acid and potash .12 and .13 per cent, respectively, and the lime 15.84 per cent. The organic portions of the

mussels decay rapidly, and serve as a fairly good source of nitrogen; and since this product is twice as rich in this constituent as average yard manure, it is well worth the expense of handling.

Lobster shells are also a waste of considerable importance, since they can be obtained at a very low cost, often for the carting. They contain, in their dry state, an average of over 4 per cent of nitrogen, 3 per cent of phosphoric acid and about 20 per cent of lime.

These products, of course, are not to be depended upon for the entire supply of constituents to crops; they are mainly useful in improving the natural quality of the soil by building it up in vegetable matter containing nitrogen. Their best use requires the addition of the minerals from other sources.

Seaweed.

Seaweed, already referred to in the discussion of potash salts, is held in high esteem in the coast states as a manurial product. In Connecticut, Rhode Island and New Jersey, the use of seaweed as a fertilizer is very general. In Rhode Island the annual value of the manure from this source has been estimated to be as high as $65,000.

In its fresh state it contains from 70 to over 80 per cent of water, and is thus economically used in that condition only near the shore. It is frequently spread out in thin layers and dried, in which condition it can be profitably transported considerable distances.

Seaweeds of different kinds differ in their content of the fertilizing constituents. Certain of them show a relatively high content of nitrogen, and others of potash, and they furnish more of these constituents than of phosphoric acid. All seaweeds contain considerable salt, though if

they are not used in too large quantities, no serious injury is liable to follow. In fact, salt in some instances is a substance of considerable indirect manurial value. Seaweed manure is certainly worthy of consideration where it can be obtained in quantity for the expense of carting.

Wood-ashes and tanbark-ashes.

Wood-ashes contain potash in one of the best forms, and were, in the early history of manuring, practically the only semi-artificial source of this element. At the present time, however, the supply is limited, and the average content of potash in the commercial article is much lower than was formerly the case.

The pure ash is not a uniform product. That from the different varieties of wood varies in composition. As a rule, the softer woods are poorer and the hard woods richer in potash than the average, the range being from 16 to 40 per cent.

Ashes also contain lime in large quantities, while phosphoric acid is contained in much smaller quantities. Wood-ashes, as usually gathered for market, however, contain very considerable proportions of moisture, dirt, and the like, which cause a variability in composition not due to the character of the woods from which they are derived. The average analysis of commercial wood-ashes shows them to contain less than 6 per cent of potash, 2 of phosphoric acid and 32 per cent of lime. Leached wood-ashes contain on the average 30 per cent of moisture, 1.10 of potash, 1.50 of phosphoric acid and 29 per cent of lime and 2 to 5 per cent of magnesium oxide.

Ashes are probably one of the best sources of potash that we have, so far as its form and combination are concerned, being in a very fine state of division, and in such

a form as to be immediately available to plants. Ashes also have a very favorable physical effect upon soils, the lime present, of course, aiding in this respect. Canada is now the main source of wood-ashes, the substitution of coal for wood making the supply in this country for commercial purposes very limited. Owing to the variability of this product, it should always be bought subject to analysis, and to a definite price a pound for the actual constituents contained in it, which should not be greater than the price at which the same constituents could be purchased in other quickly available forms.

Because wood-ashes have given excellent results, many attempts have been made to place them on the market and to sell similar products under the same name, and it is not uncommon to add to wood-ashes of low grade, fertilizer materials to fortify the product and to sell it as a high-grade material. This is especially true since the supply has become inadequate to meet the demand; therefore, great care should be exercised in its purchase.

Tanbark-ashes are much poorer in fertilizing content than those obtained from the regular commercial sources of supply. They seldom contain more than 2 per cent of potash, 1.5 per cent of phosphoric acid and 33 per cent of lime.

Limekiln-ashes are obtained in the burning of lime with wood, and are also relatively poor in potash, containing less than 1.5 per cent of potash and 1 per cent of phosphoric acid. The product is, however, much richer in lime than the average wood-ashes, often containing as high as 50 per cent of calcium oxide.

Coal-ashes.

It is believed by many that coal-ashes, because of their favorable effect upon many soils, also possess considerable

fertilizing value, whereas analyses show them to contain only traces of soluble potash and of phosphoric acid. The good results from their use is undoubtedly due to their beneficial indirect effect in improving the physical character of heavy soils.

Cotton-hull-ashes.

Cotton-hull-ashes were formerly made in considerable quantities in the southern states, where the hulls were used as fuel in the furnaces connected with gins and presses. A larger number of analyses of this product show it to be exceedingly variable in composition, ranging from 12 to 45 per cent of potash, 2 to 12 per cent of available phosphoric acid and about 10 per cent each of lime and magnesia. They can be safely purchased only on the basis of their actual composition. They are an excellent source of potash and phosphoric acid, because free from chlorids and other deleterious substances, but are not so rich in lime. They are especially useful for such crops as are injured by the presence of chlorids.

Corn-cob-ashes.

Corn-cobs are a bulky by-product and accumulate rapidly at elevators and milling plants. At many of these plants, the cobs are burned and the ash sold for fertilizer purposes. Pure corn-cob-ash thoroughly burned often contains as high as 40 per cent soluble potash. The average product varies in content of potash from 6 to 20 per cent. There is also a trace of soluble phosphoric acids. Because it is so variable it should be purchased only upon guarantee or analysis.

Cocoa shells.

Sometimes cocoa shells are ground and sold for fertilizer. They contain on the average 2.5 per cent of nitrogen, .75 per cent of phosphoric acid and 2.5 per cent of potash. They are not considered a highly valuable source of plant-food.

Green sand marl.

Marl may contain one or more of the constituents, phosphoric acid, potash and lime. Shell marls are usually very rich in lime, but contain only traces of phosphoric acid and potash. The green sand marls of New Jersey often contain very considerable amounts of phosphoric acid and potash, though they vary widely in composition. They contain, on the average, 2.20 per cent of phosphoric acid, 4.70 per cent of potash, and 2.90 per cent of lime. These constituents, particularly the potash, are, as a rule, slowly available.

Marl, however, is an important amendment to soils, not only because of its content of mineral constituents, but because these constituents are associated with products that exert a very favorable mechanical effect upon soils. Large areas of land in the state of New Jersey, formerly unproductive, chiefly because of physical imperfections, have been made very productive mainly through the application of marl.

The use of marl is now less general than when the fertilizing constituents from artificial sources were dearer, and when the labor of the farm was more abundant and cheaper. The quicker effect of more soluble fertilizer constituents has had an influence in reducing the use of marl where quick returns are desirable. Where farmers

have deposits of marl upon their own farms, or within short distances of them, or can secure it at a low price, its application is a desirable method of improving land.

The results from the use of marl are frequently due as much to the improvement of the physical condition of soils as to the fertility constituents added. Marl may be carted and spread upon the land when other work of the farm is not pressing, thus making it possible to get a considerable addition of fertility at a small expense.

Agricultural salt.

Agricultural salt which is chiefly common salt or sodium chlorid, is frequently used as a manure. It supplies no essential plant-food constituent. Its value is still disputed, though it is admitted that where its use is favorable, it is due to indirect action in aiding the decomposition of animal and vegetable matter, increasing the absorbing power of soils, and by its reaction with lime acting as a solvent for phosphates. Its most important function is in bringing the reserves of insoluble potash in the soil into solution.

Upon heavy soils, the use of common salt may prove injurious. If carbonate of lime is present in the soil, compounds are formed which deflocculate clay and render it wet and sticky.

In view of the advantages enumerated there is no good reason for paying from $4 to $6 a ton for this substance, when practically the same effect can be obtained from the salt contained in the crude potash salt, kainit, one-third of the total weight of which is common salt. This, too, may be had free of charge, or for the handling, as the market price of the kainit is based upon its content of potash.

Powder waste.

Powder waste also consists largely of common salt, though frequently containing appreciable percentages of nitrogen in the form of a nitrate. Its use can only be recommended when it can be obtained at a low price per ton, or for the handling, and upon soils that show a marked benefit from its application.

Gas lime.

"In gas works, quicklime is used for removing the impurities from the gas. Gas lime, therefore, varies considerably in composition, and consists really of a mixture of slaked lime, or calcium hydrate, and carbonate of lime, together with sulfites and sulfides of lime. These last are injurious to young plant life, and gas lime should be applied long before the crop is planted, or at least exposed to the air some time before its application. The action of air converts the poisonous substances in it into non-injurious products. Gas lime contains on an average 40 per cent of calcium oxide, and usually a small percentage of nitrogen."

Where it can be used to advantage, its cost should, as in the case of the other, be based on the proportion of actual lime present.

Gypsum or calcium sulfate.

Gypsum is a sulfate of lime, containing water in combination. Pure gypsum contains 32.5 per cent of lime, 46.5 per cent of sulfuric acid and 21 per cent of water.

Plaster of paris is prepared from gypsum by burning, which drives off the water it contains.

Gypsum, like other forms of lime, furnishes directly the element calcium, and also exerts a favorable solvent effect upon the soil. It was formerly used in large quan-

tities, particularly for clover, and it is believed that its favorable effect was due, not so much to the direct addition of lime, as to its action upon insoluble potash compounds in the soil, in setting free potash. Thus the application of plaster caused an increase in crop, because of the potash made available.

We have in the eastern states two main sources of gypsum, namely, Nova Scotia and Cayuga, New York. Nova Scotia plaster contains on the average over 90 per cent of sulfate of lime, and is, therefore, purer than that obtained from Cayuga, which often shows as low as 65 per cent of pure sulfate; the latter, however, frequently contains appreciable amounts of phosphoric acid.

Phosphorus powder.

In many places it is possible to obtain plaster which is a waste in the manufacture of phosphorus. This waste contains the plaster in a precipitated form, and frequently also contains considerable amounts of phosphoric acid. The disadvantage of this waste lies in the fact that it is frequently wet and lumpy, and thus not easily handled and distributed. Its advantage lies in its content of phosphoric acid, which ranges from 1.5 to 2 per cent, though as a rule, it can be purchased at a lower price a ton than that from the regular sources.

Calcium carbide waste.

Calcium carbide waste is a by-product obtained in the manufacture of acetylene gas. It is a solid residue consisting chiefly of calcium carbonate, calcium hydrate and water. It is valuable as a source of lime only when it may be secured at an extremely low cost because it is usually wet or otherwise in very poor mechanical condi-

tion. Unless it has been thoroughly exposed to the air, it contains small amounts of acetylene gas which is injurious to seeds. It should be exposed to the air before using or applied to the soil a few weeks before planting.

Oxy-acetylene residue.

Occasionally oxy-acetylene residue is to be had for fertilizer purposes. It is another by-product from the manufacture of gas, but it should not be confused with calcium carbide waste because its principal ingredient is potash rather than calcium. It contains from 45 to 55 per cent of potash in the form of the muriate, a high percentage of which is soluble in water.

Purchase and use of miscellaneous materials.

There are a vast number of miscellaneous fertilizing materials left unmentioned in the foregoing. For the greater part such materials are only used in localities where they may be secured at little or no cost outside of the cost of labor for hauling and distribution. In general, miscellaneous materials are very bulky and are not concentrated in the elements of plant-food even though the constituents may be contained in forms valuable for plant-feeding purposes. In many cases the indirect effect upon the physical condition of the soil is quite as valuable as the plant-food contained, as it is the case with green sand marl so extensively used in New Jersey at one time. The same is true of peat and muck. If the material is concentrated and offered for sale, it is always advisable to purchase only upon analysis or guarantee. This is true in the case of most materials which may be had at little cost because often they will not return the cost of carting and handling.

CHAPTER VII

FARMYARD AND GREEN-MANURES

Of the many materials used by the farmer for soil improvement, there is no one so thoroughly appreciated as farmyard manure. It is a natural product of the farm and returned to the land supplies humus and small amounts of plant-food which assist materially in maintaining soil fertility. Even though the amount of plant-food is relatively small and poorly balanced, its use is faultless, almost never injurious, and the advantages are easily apparent.

The advantages of farmyard manure, and green-manures as well, are in large measure the result of indirect action. They increase the water-holding capacity of soils, improve tilth or physical character and make the soil a more favorable medium for the growth and development of bacteria so pertinent to soil improvement. Different from green-manures, farmyard manure actually contains these bacteria. This is one of its greatest assets.

In spite of the many advantages of manure, little care is given it. The losses from manure are enormous each year. Unfortunately proper care means considerable inconvenience and often an outlay of capital. When these losses are efficiently checked, much greater results may be expected.

Variations in manures.

Yard manure varies in its composition according to the character of the animals producing it, the quality of the food and the object of feeding. Its composition is also influenced by the amount and kind of litter used, and its handling after it is secured. The manure from young animals is less valuable than that made when animals are full grown. Manure made from fattening animals is richer than that produced by dairy cows; animals fed upon hay and straw furnish manure much less valuable than when the cereal grains constitute a part of the ration.

Manure produced by different animals.

Horse manure is richer in nitrogen, contains less water and is less variable in composition than that obtained from cows. The manure made by animals consuming rich food is more liable to fermentation than that produced when they are fed upon bulky or watery feeds.

Horse manure is called a "hot manure" because of its tendency to hot fermentation, and is for this reason particularly useful for hotbeds, and for forcing early growth. Cow manure, on the other hand, is called a "cold manure," because less liable to fermentation. Sheep manure contains less water, and is richer in the fertilizing constituents than either horse or cow manure. Pig manure, while quite as watery as cow manure, is richer in nitrogen.

Composition of stable manure.

Manure from horse stables in large cities also varies considerably in composition. It contains on the average 75 per cent, or 1500 pounds to the ton, of water, and 25 per cent, or 500 pounds to the ton, of dry matter, which

PLATE V. — Fertilizers and Wheat.

FIGS. 8 and 9. — CONTINUOUS WHEAT CROPPING WITH AND WITHOUT GREEN-MANURES, NEW JERSEY EXPERIMENT STATION.

contains all of the manurial ingredients. The water is of no particular value; it simply increases the cost of handling. The dry matter consists of 10 to 12 per cent of ash, and from 12 to 15 per cent of organic matter. The ash contains from 8 to 10 pounds each of phosphoric acid and lime, and 6 to 8 pounds of potash; while the organic matter contains from 8 to 10 pounds of nitrogen.

Its indirect value, however, is often quite as great as, and frequently greater than, its direct value, — first, because of its vegetable matter, which materially improves the absorbing and retaining power of soils; and, second, because of the lower forms of life, or bacteria, contained in it, which induce useful fermentations in the soil. Not including the lime, the average ton of city manure contains but 28 pounds of actual fertilizer constituents.

Solid and liquid portions.

The nitrogen digested from the food, as well as a large part of the potash, is found in the liquid portions of the manure; while the nitrogen in the undigested portions, as well as a large part of the phosphoric acid, is contained in the solid residue. The nitrogen in the urine is largely in the form of "urea," a compound soluble in water, and is easily decomposed; the potash is also soluble in water. These constituents are, therefore, the most active.

Sources of loss in manures.

Manures are susceptible to two direct sources of loss, the first of which is due to fermentation, which results in the loss of nitrogen; and the second is due to leaching, which may finally result in a loss of all of the constituents, though it is confined largely to the soluble nitrogen and potash. By fermentation, the nitrogen in the manure is

changed to ammonia, usually in the form of a carbonate, which is volatile, and escapes into the atmosphere.

Care of manures.

Fermentation, causing loss, may be prevented by keeping the manure moist and well packed. The loss through leaching may be stopped if the passage of water through it is prevented. The best method to preserve it is to make it under cover, and in pits made water-tight; by such shelter and protection, the maximum amount of manurial value is obtained. The soluble constituents are prevented from being washed into the drain, and the loss of volatile compounds is reduced to a minimum. Where it is not practicable to have water-tight pits, manure should be collected in yards that drain to the center, plenty of absorbent used, drainage from the roof should not be allowed to run into the yard, and the product should be removed to the fields as often as possible.

Experiments conducted to determine the extent of the loss of valuable constituents due to improper fermentation and to leaching have shown that, under average conditions of season, the loss from exposure for six months will range from one-third to one-half of the total constituents. This loss falls upon the most active forms; the constituents remaining in the manure after being subjected to such losses are the least active and directly useful.

Manure preservatives.

The loss of ammonia, both in the stables and in manure pits, may also be prevented by the use of land plaster, phosphate rock, kainit or acid phosphate, which have the power of fixing and retaining the volatile gases.

A pound a day to each grown animal, sprinkled around in the stable, is sufficient. The same proportion and amount may be used on the manure heap. The value of this practice is, however, measured by the care of the manure afterward, since the fixed constituents are still liable to loss by leaching.

The improvement of manures.

Manures are improved as they are reduced in bulk, and as the constituents are made available or directly useful; this is accomplished by well-regulated fermentation or rotting. By well-regulated fermentation is meant that which results in the decay of organic matter with the least loss of nitrogen. The loss from fermentation is greatest when the manure lies in loose heaps, the access of air aiding the decomposition; the loss is least when it is packed and moist. The mixing of the manures of the various animals, hot and cold, also tends to reduce fermentation.

If the fermentation becomes too active, great heat is developed, which causes the rapid escape of moisture; the manure is burned and has a whitish and moldy appearance, — it is called "fire fanged." Under these circumstances there is a loss of nitrogen. The "fire-fanging" may be prevented by keeping the heap moist.

It is evident, therefore, that the improvement of manures, while it reduces the bulk and increases availability of the fertilizing elements, requires care and labor. Whether such improvement will pay or not depends, first, upon the cost of labor, and second, upon the use to which the manure will be put. Where labor is expensive, and the manure is used for the growing of such gross-feeding

crops as corn, the advantages derived are least. When the handling can be performed by the regular labor of the farm, and where the manure is applied to garden or quick-growing crops, the advantages are greatest.

On the whole, however, it is safe to estimate that the least labor necessary to get the manure from the animal to the field is the best policy; that is, while there may be loss, and while the constituents may not be so active, still, the financial results attained are, because of the saving of labor, quite as good.

There is another advantage in the careful fermentation of manures which should not be overlooked, particularly on soils poor in vegetable matter; that is, the development of useful bacteria, the work of which is so important. What has been said of yard manure is also true for other manures of the farm.

Application of yard manure.

Two points should be kept in mind in the application of yard manures, —first, that they are essentially nitrogenous products; and second, that they are particularly valuable because of the useful ferments contained in them. If too much is added at one time, a loss of nitrogen is liable to follow, and the benefits derived from the ferments are limited to small areas. The manure of the farm should be distributed as far as possible, and supplemented by more concentrated materials. Coarse manures are better adapted for heavy lands, while those which are well rotted are more useful on light soils. There should be as little handling of manure as possible, it should be carted daily when convenient, and uniformly spread, preferably on plowed ground and thoroughly worked into the surface soil. (See Fig. 6.)

Poultry and pigeon manures.

These products accumulate in considerable amounts on many farms, and are often more highly valued than their composition warrants. Many believe that they can be favorably compared with high-grade commercial fertilizers. The good results obtained are doubtless due to the readily

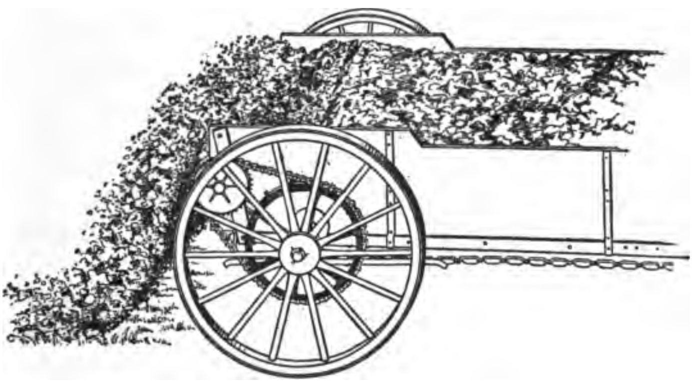


FIG. 6.—THE MANURE SPREADER IS A LABOR-SAVING DEVICE WHICH SECURES AN EVEN DISTRIBUTION.

available form in which the nitrogen exists, since the examination of these products does not show them to be particularly rich in nitrogen, or in the mineral elements of fertility, phosphoric acid and potash.

The composition of chicken manure in the fresh state is very variable not only in its content of the fertility elements but also in its content of moisture which in large degree determines its value for manurial purposes. The following table shows some of its variations:

Analysis	Per Cent			
	Water	Nitrogen	Phos. Acid	Potash
Fresh				
Cornell Exp. Station	46.84	1.38	.50	.41
Cornell Exp. Station	39.67	.75	.22	.23
New Jersey Exp. Station	55.00	1.09	.92	.45
N. Y. State Station	59.70	1.40	.92	.32
N. Y. State Station	55.30	1.14	.72	.25
Mass. Exp. Station	45.73	.79	.47	.18
Average	49.87	.92	.62	.30
Air-dried				
N. Y. State Station	7.44	1.82	2.21	1.11
N. Y. State Station	7.13	1.53	1.92	1.01
Mass. Exp. Station	8.35	2.13	2.02	.94
Average	7.64	1.83	2.05	1.02

Where the practice of storing chicken manure in a bin or discarded corn crib is common, as is so generally the case in small-fruit and poultry farms, it is not probable that the moisture is as low as in the analyses of air-dried manure given above. It is more likely to be in the neighborhood of 20 per cent and the percentage of the fertility elements is relatively less. Hence, even in the best condition, these products compare favorably with commercial fertilizers only in their content of nitrogen. Naturally they also vary in their composition, according to the character of food used in their production.

Floor sweepings from poultry houses are also valuable. The kind and amount of litter used is the cause of wide variations in the composition of such material. In general, it is very dry and fine, hence capable of even distribution.

Pigeon manure differs but little from hen manure in composition, though usually it is much drier and somewhat richer in nitrogen.

These products should be cared for, since the constituents in them serve quite as well in the feeding of plants as those contained in the more concentrated forms, though a higher estimation should not be placed upon the constituents than upon those contained in commercial forms which are quite as good.

It is a good practice to use phosphate rock or acid phosphate with small amounts of muriate of potash or kainit upon the dropping boards. This serves not only as a preservative, but tends to make the final product a better balanced fertilizer mixture.

Composts.

In addition to the yard manure, there are about most farms wastes of considerable importance, weeds, grasses, and coarse growths of many kinds, which all contain greater or less amounts of manurial constituents. These may be utilized profitably as absorbents in the barnyard. When this method is adopted, the weeds should be cut before they have matured, or they furnish an excellent means of transmitting weed seeds. These waste products may also be used in making what are called "composts." These, of course, differ according to the conditions of the farmer. Where peat or muck is available, they are more advantageous than where these products are not at hand. The main object of the compost heap is to cause a more rapid decay of such products, without the loss of essential constituents. (See Fig. 7.)

A good compost heap may be made by placing a layer of manure, then a layer of weeds or waste products of any kind, then a layer of lime or wood-ashes, the whole well moistened, and the order repeated until all of the products are used. The manure starts fermentation, the

lime or ashes aid in the rotting, prevent acidity and keep the heap alkaline, and the moisture prevents too hot fermentation. By careful management destructive fermentation is prevented, the bulk is very materially reduced and the quality of the constituents greatly improved. The chief difficulty in the making of composts, as well as with other methods used in the improvement of manures, is the expense of labor.

It pays to take good care of, and to save, manurial products, to reduce wastes and to improve the quality of the constituents by the methods suggested.

GREEN-MANURES

A great deal of misconception is prevalent concerning the value of what are termed "green-manures." These do possess a distinct value, and a proper understanding of their place in farm management will undoubtedly result in their large and better use, and in the consequent improvement of agricultural practice. By green-manures is meant any crop that is grown primarily for the purpose of improving the soil, and not for the harvested product.

"Nitrogen gatherers" and "nitrogen consumers."

In this sense any crop will serve as a green-manure, yet certain crops possess a greater value than others for this purpose, because they are able to obtain certain of their constituents from sources not accessible to all crops. In other words, the one class of plants can obtain the nitrogen necessary for their growth from the air, as well as from the soil; the other, as far as we now know, can obtain it only from the soil. These two groups of plants are, therefore, classified as "nitrogen gatherers" and "nitrogen consumers."

The nitrogen gatherers belong to the legume, or clover, family, and do not depend solely upon soil sources, but rather gather the element from outside, and thus do not reduce the content of soil nitrogen. Distinguishing features of the plants of this order are that the seeds are formed in a pod or legume, and that they have the power of acquiring at least a large part of their nitrogen from the air. These, when plowed down as green-manures, add directly to the crop-producing capacity of soils poor in nitrogen, because increasing their content of this element. In order that the plant may obtain its nitrogen from the air, however, the soil must originally contain, or must be inoculated with, a specific germ, the presence of which is manifested by the growth of nodules upon the roots, through which it is believed the nitrogen is obtained. Most well-tilled soils contain these germs in abundance.

The "nitrogen consumers" are those which can obtain their nitrogen only from the soil; these consume the nitrogen existing there, and their growth and removal exhausts the soil of this element.

Notwithstanding the very great advantages of the "nitrogen gatherers" as green-manures, they cannot be solely depended upon to increase the crop-producing capacity of the soil. That is, soils that are very poor, both in their content of nitrogen and of the essential mineral elements, cannot be made very productive by the sole use of green-manures. In fact, the green-manure crops cannot be grown with advantage unless they are supplied with an abundance of the mineral elements, phosphoric acid and potash; hence helpful green-manuring for such soils must be preceded and accompanied by liberal fertilization with the minerals, phosphoric acid, potash and lime. With these added in sufficient amounts, and

with the specific bacteria present in the soil, their use results not only in the addition of nitrogen to the soil, which may be useful for other plants, but by the accumulation of vegetable matter, which improves the physical character, usually imperfect in this class of soils. The nitrogen thus introduced into the soil is also in a very good form; that is, it has a tendency to decay rapidly and thus supply the needs of other plants, but the helpful additions to the soil are limited to organic matter and nitrogen. The mineral constituents absorbed by the crop may be more available for other crops, but they formerly existed there. No additions of these are made by the growing of the crop; hence no system of green-manuring can be made successful unless there is a previous abundance in the soil of the mineral elements, or unless these have been directly applied. (See Figs. 8 and 9, Plate V.)

The most useful crops.

The crops most useful for green-manures are red clover, crimson clover, alfalfa, sweet clover, winter vetch, soy beans and cowpeas, because of their capacity to gather nitrogen, and because of their period and time of growth. Whether these plants will gather all of the nitrogen of their growth from the air, other conditions being good, depends upon whether the soil is rich or poor in nitrogen, since it has been shown that these plants will gather at least a part of the nitrogen from the soil in preference to that from the air, unless they are starved in respect to soil nitrogen. The amounts that may be gathered from the air, therefore, are not measured by the total content of nitrogen contained in the plant grown (which may, in the case of good crops, amount to as much as 200 pounds to

the acre, sufficient for the use of several good crops of wheat, or other cereal grains), but apparently by the poverty of the soil in this element. The fact that an accumulation of nitrogen does occur has been distinctly shown, and their continuous growth, therefore, would have a tendency to over-enrich the soil in this constituent, unless accompanied by an abundant supply of minerals, particularly in the improvement of light lands and in orchards and vineyards, for which their right use is very beneficial.

Experiments conducted in this as well as other countries show that the nitrogen so gathered and stored in the soil may be readily obtained by cereal and other nitrogen-consuming crops. In experiments conducted by the New Jersey Experiment Station, on a poor, sandy soil, in which the mineral elements, phosphoric acid, potash and lime, only, were added, a crop of cowpeas gathered, in the roots and tops, 75 pounds of nitrogen, equivalent to that contained in 470 pounds of nitrate of soda, which when turned under was capable of feeding a rye crop with sufficient nitrogen to produce a most excellent crop, quite as good as that grown on land long under cultivation and well manured. Further experiments conducted with crimson clover show that the nitrogen gathered was capable of supplying the needs of fruit trees quite as well as when the nitrogen was applied in the immediately available form contained in nitrate of soda.

If it were necessary to do so, numerous experiments might be cited to show that the nitrogen is gathered from the air by these plants, and that it is capable of providing that required for those other crops which can obtain it only from the soil.

Green-manure crops that consume the nitrogen in the soil.

In addition to the legumes, other crops are used as green-manures. Chief of these are rye, wheat, buckwheat, mustard, oats, barley and rape, not because they are capable of gathering nitrogen directly, but because their period and time of growth are such as frequently to enable them to serve a very useful purpose in preventing losses in fertility. In the growth of these crops, however, the only real addition to the soil is the amount of non-nitrogenous organic matter contained in them. The nitrogen gathered is in direct proportion to the amount contained in the soil and the relative feeding capacity of the plant. The nitrogen is not obtained from the atmosphere, and the soil has not accumulated nitrogen by virtue of their growth, and is not richer in this element, except in so far as by their growth they prevent the escape of readily available nitrogen into the drainage waters. The nitrogen gathered is "soil nitrogen," and its conversion into a crop simply results in changing its form and place. The specific use of these crops, therefore, so far as directly contributing to the fertility of the soil is concerned, is to prevent the possible loss of nitrogen and other constituents by leaching, which is more liable to occur on uncropped soils, though they further contribute toward soil improvement by accumulating stores of non-nitrogenous vegetable matter.

These crops, also, in order that they may produce largely, must be freely supplied with the mineral elements, as well as with nitrogen in some form, and cannot be regarded as a substitute for the leguminous crops, or as a substitute for commercial fertilizers in the permanent improvement of the soil, in the sense that they actually contribute to

its content of fertility elements, — an opinion apparently held by many who have observed the good results that often follow their use. (See Fig. 10, Plate VI.)

Mixtures are advisable.

It is often advisable to mix legumes with non-legumes on the principle that a variety of seeds often make a better stand. This is particularly true when green-manures are used between cultivated crops. The mixture used must be made up so as to include crops which grow through the same period of time, crops which may be expected to grow when planted at the same time. For example, a mixture composed of sixty pounds of rye, twenty pounds of winter vetch and ten pounds of crimson clover give most excellent results in southern New Jersey, whereas, conditions in northern New Jersey are not suitable for crimson clover.

Precautions in the use of green-manures.

In general, fields covered by green-manure crops should be plowed at the customary time regardless of the growth made by the plants. Legumes accumulate the greater proportion of their nitrogen supply in the early stages of growth, and it is not wise to disturb the farm system of labor. If too great growth is made by the crop, it should be mowed and harrowed before plowing. In case a heavy crop is plowed down, a dry season may cause a lessening of the moisture supply brought about by the formation of an impervious layer of organic matter which, also, may not decompose readily, resulting in serious injury to the physical condition of the soil.

Non-legume crops contain, as a rule, less nitrogen, and besides, that contained in them is apparently less avail-

able than the nitrogen contained in the green-manures from the leguminous crops. In their growth, too, they appropriate the immediately available nitrogen of the soil, and convert it into the less available organic form; hence the crop that follows is frequently unable to obtain its food as readily as would have been the case, provided the green-manure crop had not been grown, and furthermore, legumes may be the cause of too much nitrogen in organic form, frequently experienced by potato growers. Therefore, while the practice of using green-manures is a desirable one when properly understood, it should not be regarded as a means by which soils may be directly enriched, except in the case of the plants of the legume family, where nitrogen is really added to the soil. In the case of all other crops, the benefit is indirect, and is in proportion to the amount of minerals added.

CHAPTER VIII

LIME AND CALCIUM COMPOUNDS

THE foregoing discussion has concerned almost entirely materials which actually supply the plant with needed food — with one or more of the essential elements of plant-food. Lime, though in a few instances a food, is of value more particularly because its indirect action is important. It is not only one of the oldest of all manures, but it is, also, the most popular and continues to increase in use. In spite of these facts it is still the foundation of considerable misunderstanding, probably because its action is not restricted to any particular channel. It is known that by some plants it is used as a food and that its greatest asset is its mechanical, chemical and biological activity.

Lime is contained in most soils in sufficient quantities for the support of abundant plant growth. Yet, there are soils, particularly light, sandy soils, to which the addition of lime directly promotes plant growth. Permanent pastures of long standing which were originally well supplied with lime have through years of leaching become deficient in this element in the surface soil, whereas the same soil, had it been thoroughly cultivated year after year, would contain sufficient lime for plant growth because the cultivation would tend to counteract the downward movement of the lime and hold a sufficient quantity in the surface soil.

There is also a number of plants which require much larger quantities of lime for maximum growth than is naturally contained in soils. Of these plants the legumes, especially alfalfa, form the largest group.

OCCURRENCE OF LIME

It is fortunate that lime occurs in great abundance. Reliable estimates show that about one-sixth of the rock mass of the earth's crust is composed of calcium compounds. Vast tracts of country are composed of nothing but limestone and a large number of the more common minerals contain high percentages of calcium. Pure lime is insoluble in pure water but is readily soluble in water containing carbonic acid, such as rain water or soil water. Such waters aid greatly in the disintegration of the rock or mineral and carry the lime to the soil.

In nature, lime exists chiefly as calcium carbonate or carbonate of lime in the forms of limestone, marble and chalk. It also exists in combination with magnesium and other chemical elements. Oyster shells and clam shells are composed almost entirely of calcium carbonate. Gypsum, a different chemical compound referred to elsewhere, also occurs in nature.

FORMS ON THE MARKET

Caustic lime.

Limestone as it occurs in nature is in the form of a hard rock and as such it is incapable of distribution and likewise incapable of exerting the many functions for which lime is used. Limestone is really a chemical combination of calcium oxide and carbonic acid. When

thoroughly heated, it gives up the carbonic acid, which goes off as a gas, leaving calcium oxide, commonly known as lime, and often termed "burned lime," "quick-lime," "stone-lime" or "lump-lime." In fact, 100 pounds of pure limestone when properly burned gives up 44 pounds of carbonic acid, leaving 56 pounds of calcium oxide. This material — calcium oxide — has become known as actual lime through the practice of farmers, manufacturers and chemists who are accustomed to using it as a basis of comparison in estimating the quantities of lime in the different forms. It was the custom of farmers located in limestone regions to maintain kilns and do the burning themselves, but the increased cost of wood and high cost of coal for burning and scarcity of labor have made it practically impossible for the farmer to compete with the manufacturer and the home practice of burning has been abandoned.

The resultant material after burning must be slaked before it is applied to the soil. This is done by adding water, which is absorbed and the lime falls to a fine powder ready for distribution. When chemically pure, burned lime contains 100 per cent of actual lime (calcium oxide), but the commercial product seldom contains more than 92 per cent and varies from 78 to 96 per cent of actual lime, depending upon the amount of impurities in the limestone used for burning.

Ground limestone.

By the use of powerful grinding machinery used in the manufacture of cement, ground or pulverized limestone has been put upon the market. The rock limestone is simply ground, bagged and sold to the farmer. Chemically pure ground limestone contains 56 per cent of actual

lime, though the commercial product seldom contains more than 52 per cent and varies from 42 to 54 per cent of actual lime.

The action of this material is dependent in large measure upon the fineness of division. Products are upon the market which vary from coarse pieces to a very find powder, 85 per cent of which will pass through a 200-mesh screen. The very coarse material acts very slowly and should be avoided except perhaps for use upon very light soils. In general, 75 per cent ground limestone should pass through a 100-mesh screen for profitable agricultural use.

Calcium-magnesium lime.

What is termed "marble lime" is made from pure limestone, and the burned lime thus obtained is practically pure oxide of lime. Limestone, so called, is not always pure. Sometimes it is a mixture of lime and magnesia, in which case it is the mineral "dolomite" and is termed "magnesian limestone." A very large quantity of the lime used in the eastern states is the magnesium form. The burned lime from the magnesian limestone contains from 50 to 60 per cent of calcium oxide, and 20 per cent or more of magnesium oxide. Similar ground products contain 25 to 30 per cent of calcium oxide, and 10 per cent or more of magnesium oxide. In some instances, the magnesium oxide is of value, though it is rather inert in its effect, and is less useful than the lime. It is believed to have a beneficial effect upon the bacterial activity of soils. A safe method in the purchase and use of lime is to adjust the price to the proportionate percentage of actual lime present, practically in the ratio of 10 to 7.

Ground burned lime.

Ground burned lime is identical to quick-lime, lump-lime or burned-lime except that the manufacturer grinds it immediately upon burning and bags it to make it ready for shipment. This lime requires no slaking by the farmer and its shipment in bags facilitates handling and distribution.

Hydrated lime.

Burned lime absorbs water freely. When water is added, the resultant product is calcium hydrate or hydrated lime. Burned lime is usually hydrated or slaked by the farmer before application to the soil is made, but recently this form of lime has become a commercial product. The burned lime is ground and water added in the form of steam which produces a very finely divided product. When pure and thoroughly hydrated, this material contains 75.7 per cent of actual lime, though the commercial product varies from 64 to 72 per cent of actual lime. In case the process of hydration has been incomplete, the percentage of actual lime may be much greater.

Air-slaked lime.

Quick-lime absorbs moisture, and slakes when exposed to the atmosphere. Lime thus slaked is called "air-slaked lime," and is usually less completely changed to a hydrate than when water is added. Quick-lime also absorbs carbonic acid from the air, and changes back to the limestone form.

Oyster shell lime.

Oyster shells are nearly pure carbonate of lime, and oyster shell lime, while practically pure lime, so far as

this element is concerned, is usually mixed with more or less dirt and other impurities, and is, therefore, not as rich in lime as that derived from pure limestone. When properly burned, it contains from 80 to 90 per cent of actual lime.

Ground oyster shell lime is an excellent source of lime, containing from 85 to 95 per cent of calcium carbonate, equivalent to 48 to 53 per cent actual lime. This product also contains minute quantities of nitrogen and phosphoric acid. In some cases as much as seventy-five cents' worth of these elements is contained in a ton of the material. Ground oyster shell lime decomposes very readily in the soil, and the fineness of division is not such an important factor in determining its value as it is in the case of ground limestone.

Shell marl.

Shell marl is one of the less important sources of lime. There are a number of deposits in Atlantic coast states, but few of these are worked. This product varies much in its content of lime according to the amount of impurities laid down with it, though it often contains as high as 95 per cent of calcium carbonate, equivalent to 53 per cent of actual lime. When it may be secured reasonably, it is one of the best forms of lime, because it is really a material which was at one time in solution, and hence, its extreme fineness of division makes its action immediate and complete.

ACTION OF LIME IN SOILS

Lime has already been referred to as a plant-food. Its indirect actions are numerous, producing many specific

PLATE VI. — Wheat and Potatoes.

Fig. 10. — Wheat Grown as a Winter Cover-crop Preceding Potatoes, Freehold, New Jersey.

Fig. 13. — Making an Application of One and One-half Tons of Quicklime to the Acre for Alfalfa after Potatoes.

effects which are not limited to any one field. It affects the soil itself, changes its texture and mechanical properties, such as its power of taking up and holding moisture. It acts upon the supply of plant-food stored in the soil and assists the decomposition of organic matter and mineral substances. Most important of all is the influence which lime exerts upon the microörganic life of the soil, so essential in changing dormant to active forms of plant-food. Hence, the activities of lime in the soil may be said to be threefold,—mechanical, chemical and biological.

Mechanical effects of lime.

It is often stated that lime makes heavy soils lighter and light soils heavier. This is the apparent effect rather than the actual. Applications of lime upon heavy soils make them less sticky, more crumbly, more friable, more easily cultivated, and water passes through them more rapidly as the result of increased porosity. This condition is brought about by the flocculation or aggregation of the fine clay particles preventing shrinkage in dry weather.

Upon light soils the reverse is true. An application of lime tends to increase the cohesive power of the soil, resulting in a greater water-holding capacity, as well as increasing the power to absorb moisture from below by capillarity. Light, sandy soils may, however, be injured by large applications of lime, especially if it is in the caustic form which causes a greater porosity and allows water to pass through too rapidly. Upon muck or peat soils, lime should always be mixed with the surface soil. A layer of lime spread over the surface of such soils has a tendency to exhaust the organic matter, and injury may follow especially in case of drouth because the water-holding capacity is decreased.

Chemical effects of lime.

Roots of peanuts exude small quantities of acid during growth, and likewise organic matter during decomposition gives off acids. This is really a provision of nature because the acids produced in this manner aid in making the soil stores of mineral plant-food available, but an accumulation of these acids which is bound to follow is sure to give rise to compounds poisonous and harmful to vegetable life. Lime has long been used to neutralize these so-called soil acids, and this chemical effect is undoubtedly the best known of all the advantages derived from the use of lime. To correct acidity, or sweeten sour soils, is a function of lime thoroughly appreciated and well understood. This practice also kills many of the lower forms of plant life which flourish on sour soils and allows the more nutritive plants to grow.

Lime supplies a necessary base.

Soils that contain insufficient basic compounds such as carbonates of calcium, magnesium, potassium and sodium, are not in a condition to produce maximum crops. The absence of such compounds permits the accumulation of acids. Under such conditions normal decomposition of organic matter, the formation of nitrate nitrogen from ammonia, and organic matter, and the utilization of atmospheric nitrogen by bacterial activity are severely hindered. While the correction of acidity and the addition of lime as a basic-compound are more or less analogous, it is thought best to mention the latter to point out the fact that the addition of just enough lime to correct acidity may not be sufficient to promote chemical and bacteriological functions. (See Figs. 11 and 12, Plate VII.)

Lime assists the decomposition of organic matter.

Soils supplied with calcium carbonate or other basic-compounds admit the normal decomposition of organic matter which is the foundation of the formation of nitrate nitrogen under conditions permitting the proper circulation of air and moisture. Soils lacking calcium carbonate or other basic-compounds permit the rapid accumulation of free acids which poison the organisms responsible for decomposition.

Lime makes soil potash available.

Many soils contain potash in large quantities in a form not usable by plants. Soluble calcium compounds are of prime importance in the conversion of some of this soil potash into forms available for use by plants. The effect of soluble calcium compounds in making the insoluble potassium compounds of the soil soluble may be readily seen upon heavy clay soils or heavy limestone soils where good crops of clover are produced annually without the addition of potash salts. Though all of the conditions influencing this change are unknown, yet it is safe to say that it is primarily dependent upon the nature of the potassium compounds existing in the soil.

Lime makes soil phosphates available.

Compounds containing phosphorus, especially phosphates of iron and aluminum, occur in many soils. These particular compounds are very slowly soluble in soil water. The change to a more soluble form is brought about more readily in the presence of lime, especially when it is in the form of carbonate or hydrate. It was thought for a long time that use of lime where superphosphates are used in

abundance rendered the phosphoric acid less efficient as a plant-food, but experiments have shown this theory to be greatly overdrawn.

Less plant-food required.

Careful study of the foregoing paragraphs shows clearly that less plant-food is required where lime is used in liberal quantity. In general, less nitrogen, phosphoric acid and potash need be added to soils well supplied with lime and in good tilth for satisfactory crop production than in the case of soils deficient in lime.

Injurious chemical effects.

Lime hastens the decomposition of organic matter and the formation of nitrates, as previously stated. If conditions are unfavorable to the formation of nitrates, the decomposition of organic matter may be accompanied by a loss of nitrogen which escapes into the air as a gas. In case all conditions are favorable for nitrification, nitrate nitrogen may be formed in the soil more rapidly than the plant-life present is capable of utilizing it and much of it would be leached from the soil and lost in the drainage water. This is more likely to occur in connection with the use of burned or hydrated lime, especially on light soils, than with the use of ground limestone.

Effects of gypsum.

Gypsum, land plaster or calcium sulfate previously mentioned should not be confused with lime, though it is similar in the respect that it carries the element calcium. Unlike lime, gypsum will not correct acidity, and its continued use actually makes soils more acid, but it has the advantage of changing ammonium carbonate which is

volatile into the stable form of ammonium sulfate. For this reason it is exceptionally useful as a deoderant and absorbent in stables. It tends to preserve the nitrogen of manure rather than to expel it as do burned and hydrated lime.

BIOLOGICAL EFFECTS OF LIME

Few farmers realize or appreciate the practical importance of the biological effects of lime which are so important in controlling the various fermentative actions which go in so abundantly in all soils. Lime not only assists the decomposition of organic matter but it furnishes a necessary base with which nitric acid combines in the process of nitrification, and it is most important in the formation of nitrate nitrogen. Lime creates conditions favorable for the growth and development of soil organisms which are so important in gathering and fixing nitrogen, and at the same time destroys many kinds of bacteria and fungi which are the cause of plant-diseases such as "rust," "smut" and "club-root."

Biological effects may be harmful.

Too great an application of lime, causing a strongly alkaline soil, may prevent the normal process of decomposition and nitrification. Fermentation of organic matter goes on when there is a certain amount of alkalinity present; while, on the other hand, the presence of acidity seems to retard and check it. Too great an amount of alkalinity, however, would retard fermentation as much as too great acidity. This is true more particularly in case of caustic lime, but the duration of the injury ceases when it has been changed to the carbonate form.

There are some plant-diseases, notably potato scab, which thrive far better under alkaline soil conditions, but in no case is the disease caused by the application of lime. The bacteria or fungi which cause the disease must be present in the soil or subsequently introduced. Lime merely creates conditions favorable for the spread and development of the disease-causing organism and for the development of the disease.

It might be added that the character of native vegetation is greatly influenced by the presence or absence of lime in soils just as farm crops are influenced. Chestnut trees, rhododendrons, arbutus, blueberry, huckleberry and many other wild plants prefer soils not rich in lime; while, on the other hand, leguminous crops, alfalfa, clovers, soy beans, cow peas, beans, peas, wistaria, locust trees and the like, prefer soils exceptionally well supplied with lime. The common weed known as sheep sorrel, and many crops including the watermelon, strawberry and cranberry, thrive on soils distinctly acid.

THE USE OF LIME

A knowledge of the forms of lime and the action of lime in a soil is contingent with the efficient use of lime which is to a greater or less extent an individual problem with each farmer because soils, crops and farming systems vary so widely, but there are a few fundamental principles which should be thoroughly understood by every farmer. These principles involve a number of questions the most important of which are: do soils need lime; how much lime should be used; how and when should it be applied; and what form of lime is best suited to existing conditions?

Do soils need lime?

There are a number of ways to determine whether a soil needs lime. It is known that lime leaches out of soils, that crop production and decomposition of organic matter increase acidity, and therefore the application of lime becomes necessary in the course of time. For these reasons the history of any field is an important guide. There is a common weed — sheep sorrel — which in the absence of cultivation and crowding thrives in acid soils, and it is one of the best natural indications of the need of lime. An attempt to raise red clover — a crop decidedly responsive to lime — is a reliable method to determine the character of soil so far as lime is concerned if there is no serious lack of potash which may have a similar effect.

There are a number of chemical tests which are very accurate but are not entirely satisfactory for the farmer's use. The litmus paper test serves its purpose in the laboratory, but it is not always reliable in the field. It is based on the fact that blue litmus paper turns red when placed in contact with acid, and red turns blue when in contact with basic compounds such as lime. Hence an acid soil will turn blue litmus red, and if such is the case, the need of lime is indicated. When a little finely pulverized soil fails to show any visible effervescence when it is covered with dilute hydrochloric acid, it is a good indication that the proportion of carbonate of lime must be below what is desirable for the healthy growth of vegetation, but this is not an infallible rule nor a positive sign that the soil contained excessive amounts of acid. Chemical tests of absolute dependability may be made in properly equipped laboratories, and it is well for farmers to obtain such tests. But the

indications at the disposal of the farmer should be sufficient when good judgment is exercised.

The application of lime.

The character of soil, kind of crop and character of farming are the most important factors upon which the use and application of lime depend. In general, however, it is better to make frequent and small applications than large applications every five or ten years. On soils which are poor, light and lacking in organic matter or dry, the application should be small, varying from 500 to not more than 1200 pounds of actual lime or its equivalent to the acre every two or three years. On heavy soils composed largely of clay and well filled with organic matter, the application should be much heavier, from 1200 to 3000 pounds of actual lime or its equivalent to the acre every two or three years. Soils of this description will make better use of larger quantities, and there is less danger of injury to soil or crop. If ground limestone is used, even larger amounts may be applied.

There are certain crops which respond greatly to lime, others that are negative and still others that are actually injured when lime is present in the soil in any quantity. The farmer must study the particular crop he is growing and the effect lime has upon its development in order that the application of lime may be properly adjusted to the requirements of the crop as well as to the soil.

When and how to apply lime.

The time of application depends primarily upon convenience, but there are a few general rules which it is well to follow. Lime should be applied to the surface

after plowing and harrowed in, because it works downward and naturally leaches into the lower layers of soil. For best results it should be applied at a time when the soil is well filled with organic matter and a crop should be planted soon after its application to utilize the nitrate nitrogen which is a natural result of its action upon the organic matter.

While it is often most convenient to apply lime in early spring, on most farms, the rotation practiced or the crop will in many cases fix the time of application; for example, previous to seeding clover or alfalfa. In the case of caustic lime, applications may be made upon plowed ground in fall without injury to seed. When barnyard manure or fertilizer containing nitrogen in the ammonia or organic form are to be applied to the same field with caustic lime, the manure and fertilizer should be well incorporated with the soil and the lime applied after an interval of two weeks or more.

The form of lime to use.

It is possible to conceive of conditions under which a specific form of lime should be used to the entire exclusion of other forms; and yet, in general, the form of lime to use depends primarily upon the cost of a pound of actual lime or calcium oxide, and the quantity used should be regulated by conditions of soil, kind of crop and the like. In other words, cost is an important factor. The farmer buying lime should first consider the cost of actual lime in the various forms at his disposal. The cost of a pound of actual lime is easily calculated by multiplying the guaranteed percentage of calcium oxide by twenty and dividing the price of a ton by it. The following table shows this calculation clearly:

COMPARATIVE COST OF ACTUAL LIME IN DIFFERENT FORMS

KIND OR FORM OF LIME	GUARANTEED PER CENT ACTUAL LIME	POUNDS ACTUAL LIME IN ONE TON	ASSUMED QUOTATION ON ONE TON LIME DELIVERED	CALCULATION OF COST OF ONE POUND OF ACTUAL LIME	COMPARATIVE COST OF ONE POUND OF ACTUAL LIME
Burned lump lime .	90(× 20) =	1800	3.50	$\frac{3.50}{1800}$	$.0019
Ground burned lime .	90(× 20) =	1800	6.00	$\frac{6.00}{1800}$	.0033
Hydrated lime . . .	70(× 20) =	1400	6.00	$\frac{6.00}{1400}$	.0042
Ground limestone . .	50(× 20) =	1000	3.00	$\frac{3.00}{1000}$	.0030

At the same time, the cost and convenience of handling must be considered. The user of lime is not concerned with the cost of transportation by the railroad so long as the delivered price shows the cost of actual lime to be reasonable. The cost of handling after the lime arrives at the railroad station is the next important consideration. The concentration, ease of handling, storage and distribution, and the probable cost of each operation are items of practical significance. In general, the less concentrated forms may be handled with greater ease and less expense, but the cost of cartage is practically doubled and it might be better to purchase one of the more concentrated forms, especially if the farm is located at considerable distance from the railroad.

As a factor of cost, fineness of division should not be overlooked. Good burned lime showing a relatively high percentage of actual lime, indicating comparative freedom from impurities, properly slaked, is as fine a powder as it is possible to obtain and there need be no doubt of

its immediate action. The fineness of ground limestone is entirely arbitrary with the manufacturer. The finer it is, the quicker and more complete will be the action. A guarantee of the size of particles is important and should be insisted upon before purchase. Ground limestone capable of passing at least 75 per cent through a 100-mesh screen or sieve gives prompt action and is suitable for use in most cases. A still finer product is more prompt and a coarser product less prompt in action. If conditions are such as to warrant the use of the coarsely ground limestone, it has the advantage of costing less.

Peculiar conditions often exist or arise which help to determine the form of lime to use regardless of the foregoing suggestions relating to purchase. Crops sensitive to alkaline soil conditions are injured less and thrive better when the slower acting carbonate is used. This has already been referred to in greater detail. For quick-growing crops requiring a soil rich in organic matter and available plant-food, burned lime is preferable because it brings about chemical changes of the organic plant-food more quickly, causing a rapid and succulent growth. One point of importance in this matter is the solubility of the different forms. The burned lime which is changed to the hydrated form by slaking is more soluble in water, and hence becomes distributed throughout the soil more readily than the carbonate. It is true that slaked lime changes to the carbonate form, but this change requires some time even under the most favorable conditions and during this period the slaked lime is more active chemically.

Distribution of lime. (See Fig. 13, Plate VI.)

Lime, no matter in what form, should be evenly distributed and when possible uniformly worked into the

surface soil. Burned lime should be worked into the surface soil as soon as practicable after application and before it has had time to change to the carbonate form. A uniform distribution is not difficult when machinery is used. Lime distributers are very efficient and make a profitable investment. If no machinery is available and the lime is spread by shovel from the back of a wagon, the soil should be worked very thoroughly immediately after application.

Analysis and guarantee.

Nearly all states now require guarantees showing chemical and mechanical analyses of all forms of lime, and the farmer should be careful in the purchase of lime to require such an analysis and guarantee. Such an analysis should show the form of lime, the percentage of actual lime, the percentage of magnesia, the impurities and the fineness of division in the case of carbonate of lime.

CHAPTER IX

PURCHASE OF FERTILIZERS

COMMERCIAL fertilizers, in the form in which they are obtained by farmers, are made up of varying proportions of one or more products from each class of fertilizing materials described. That is, every manufacturer is obliged to go to these sources of supply, whatever may be the name given to the finished product or mixture. Hence the fertilizing materials described are not regarded as commercial fertilizers in the same light as those which they are able to purchase under brand names from their local dealers. In the first place, a specific fertilizing material, as distinct from a manufactured fertilizer, contains, as a rule, but one of the essential fertilizing elements, and its use under average conditions would be far different from one which contains two or all of the essential fertilizing elements. The materials, therefore, are classed as nitrogenous, phosphatic and potassic, according to whether the material contains nitrogen, phosphoric acid or potash as its chief or its only constituent element; and these different classes, too, may be again subdivided into two distinct groups, the first including "standard," or high-grade materials, and second, "general," or low-grade materials. This classification is of the utmost importance.

STANDARD HIGH-GRADE MATERIALS

Nitrate of soda, sulfate of ammonia and dried blood are, for example, standard or high-grade nitrogenous materials, and belong to the first group. They are "standard" because they do not vary widely in their composition. A definite quantity can be depended upon to furnish not only practically the same amount of the specific constituent, but to furnish it in a distinct and definite form, which is identical, from whatever source derived. For example, commercial nitrate of soda does not vary materially in its composition, and the nitrogen in it is always in the form of a nitrate. The same is true of sulfate of ammonia. One ton will furnish practically as much nitrogen as any other ton, and it is always in the form of ammonia. It is also practically true of high-grade dried blood. Each lot contains this specific form of organic nitrogen, and will always decay at practically the same rate, if used under the same conditions. They are also high-grade products because they are richer in the constituent element, nitrogen, than any other, and because this element is immediately or quickly available.

The South Carolina, Florida and Tennessee rock phosphates differ from the nitrogenous materials mentioned, inasmuch as, in their raw state, they are not directly useful as fertilizers, — they are not sources of available phosphoric acid. Hence the standard supplies of phosphoric acid are derived from these materials after they are manufactured into superphosphates. The various kinds of these may be regarded as high-grade in the sense that they always possess a high content of available phosphoric acid. They are standard, too, not only because

of this, but because they do not vary widely in their composition. A definite amount from each class can be depended upon to furnish practically the same amount of available phosphoric acid. For example, a ton of South Carolina rock superphosphate, from whatever manufacturer obtained, will not vary widely in its content of phosphoric acid, and will always act in the same way under similar conditions. The various German potash salts are also standard and high-grade, since the composition of each grade and kind is practically uniform in its content of potash, which will always act in the same way under the same conditions, and since they are richer in the specific element, potash, than other potassic compounds suitable for the manufacture of fertilizers.

These various standard, high-grade products, when used in the manufacture of fertilizers, make what are called "chemical fertilizers," because they are really crude chemical compounds, and furnish the particular fertilizer elements in their most concentrated and active forms.

FERTILIZING MATERIALS WHICH ARE VARIABLE IN COMPOSITION

The products which are included in the second group differ from the others, in that they not only vary in their content of the specific constituent, or in their composition, but they are also variable in the sense that the constituents contained in them do not show a uniform rate of availability. For example, ground bone varies in its composition owing to its source and the method of treatment, and the availability of the constituents, nitrogen and phosphoric acid, also varies because of these condi-

tions, and because of its mechanical condition or degree of fineness. Different samples of bone derived from the same source, treated in the same way, and ground to the same degree of fineness, would be regarded as standard, but because these conditions differ, bone from different sources cannot be depended upon to act in the same way under the identical climatic and soil conditions. This is also true of tankage, which varies, not only in the total amount of the constituents contained in it, but in the proportion of its two chief constituents, nitrogen and phosphoric acid, and in the rate at which they become available to plants. In this class belong, in addition to the bone and tankage, ground fish, and the various miscellaneous products. They cannot be depended upon, either in respect to their composition or their availability of the essential constituents — important advantages possessed by the standard products.

HIGH-GRADE AND LOW-GRADE FERTILIZERS

The fertilizers manufactured from these two classes of raw materials will therefore differ. Those made from the first class are always high-grade, both in reference to the quality and quantity of the constituents that may be contained in a mixture. Those manufactured from the second group are not high-grade, so far as the form of the constituent is concerned, though they may be high-grade in the sense that they contain large amounts of them. In the manufacture of fertilizers, too, as a rule, all three of the essential constituents are introduced, and the buying of a fertilizer is really the buying of the three constituents, nitrogen, phosphoric acid and potash. Hence, the more concentrated the product, or the richer

it is in these constituents, the less will be the actual cost of handling per unit of the constituents desired, and the higher the grade of the materials used, the greater the proportionate activity of the constituents.

The "unit" basis of purchase.

In commercial transactions in fertilizing materials, two systems of purchase are used. The first is known as the "unit" system, in which case the quotations, or prices are based on the unit. A unit means one per cent on the basis of a ton, or 20 pounds. For example, a unit of available phosphoric acid means 20 pounds, and a quotation of $1 a unit would be equivalent to a quotation of 5 cents a pound. In the trade, sales are always made on this basis. The system is also applied to such nitrogenous products as blood, meat, hoof meal, concentrated tankage and the like. The price is fixed at so much a unit of ammonia. This system is probably the most perfect, and certainly cannot but be satisfactory to both the dealer and the consumer. It results in the consumer receiving exactly as much as he pays for, and the producer is paid for exactly what he delivers. The number of units in each material sold is fixed in each case by the chemist to whom the samples are referred.

The "ton" basis of purchase.

The other method of purchase is known as the "ton" basis, and is used almost exclusively in the sale of other materials than the standard products mentioned, and manufactured fertilizers. This system works well with standard high-grade products, since the ton price is, in this case, a fair guide as to the cost of the constituents, though it cannot be as satisfactory as the other, since

even the best materials may vary sufficiently to cause a difference in actual cost of the constituents, even though the price per ton remains unchanged. In this method, the products are usually accompanied by a guarantee, the purpose of which is to indicate the minimum amount of the constituents contained in the material.

The necessity of a guarantee.

In the purchase of mixtures, consumers should demand that they be accompanied by a guarantee, because they are unable to determine the kind and proportion of the different materials entering into the mixture, either by its appearance, weight or smell. In mixing, too, an opportunity is afforded for disguising poor forms of the constituents, particularly nitrogen. That is, in a mixture of nitrogenous materials, potash salts and superphosphates, it would be a difficult matter to determine, by mere physical inspection, the proportion of the nitrogen which had been supplied in the form of horn meal and of blood, and the statement of the manufacturer on this point would be valuable in proportion to his reliability. The fact that in mixtures it is impossible for the consumer to distinguish or determine the proportions, amounts or kinds of the constituents is so fully recognized that it has resulted in the enactment of laws in most states, which require that manufacturers or dealers in fertilizers shall state the actual amounts of the different constituents contained in their products, as well as the sources from which they were derived, and which fix a penalty for any failure to comply with the law in this respect. A chemical control is in these cases provided for, and it has been of great service both to the good manufacturers, because it tends to reduce the number of low-grade brands which would naturally

PLATE VII. — Fertilizers and Rye.

Figs. 11 and 12. — Rye with One-half Ton of Lime and without Lime.

come into competition with them without such protection, and to the consumers, because it protects them from fraudulent products.

Laws alone do not fully protect.

Laws alone, however, are not sufficient to fully protect the farmer in this respect. He must possess, in addition, a knowledge of what constitutes a good fertilizer, and must be able to determine from the analysis whether there is a proper relation between the guarantee and the selling price, and whether the materials that have been used are of good quality. The fact that there is a very decided lack of the right sort of intelligence on this point, is shown by the results of the work of the different fertilizer control stations. These demonstrate clearly that farmers do, in many cases, pay exorbitant prices for their fertilizer constituents, not because the manufacturer did not sell what he claimed to sell, but because the price charged by the dealer was far in excess of that warranted by the guarantee. For example, it has been repeatedly shown that of two farmers in the same neighborhood, the one who studies the matter and understands the relation of guarantee to selling price, may pay 15 cents a pound for his nitrogen, while the other, who does not study the matter, buys on the ton basis, and does not know that there should be such a relation between the two, may pay 30 cents a pound for the same quality of the same constituent. This may be illustrated by the following examples:

Two brands are offered, made up from the same kind and quality of materials. No. 1 is guaranteed to contain:

Nitrogen	1%
Phosphoric acid (available)	6%
Potash	1%

and sells for $20 a ton; and No. 2 is guaranteed to contain:

Nitrogen	4%
Phosphoric acid (available)	8%
Potash	2%

and sells for $22 a ton. The farmer who buys on the ton basis, or is guided only by the ton price, will be induced to purchase the No. 1 brand, because by so doing he apparently saves $2 a ton. The one who studies the relation of guarantee to selling price will purchase the No. 2 brand, because he finds, from a simple calculation, that it furnishes the constituents at just one-half the cost per pound of the No. 1 brand, notwithstanding the higher ton price, which is shown by the following calculation:

No. 1

			Lbs. to the ton	*Cts. to the lb.*	
Nitrogen	1% × 20	=	20	@ 30	= $6 00
Phosphoric acid (available)	6% × 20	=	120	@ 10	= 12 00
Potash	1% × 20	=	20	@ 10	= 2 00
					$20 00

No. 2

			Lbs. to the ton	*Cts. to the lb.*	
Nitrogen	4% × 20	=	80	@ 15	= $12 00
Phosphoric acid (available)	8% × 20	=	160	@ 5	= 8 00
Potash	2% × 20	=	40	@ 5	= 2 00
					$22 00

In reality, the fertilizer at $22 a ton is cheaper than the one at $20 a ton.

	No. 1	*No. 2*
Nitrogen	$0 30	$0 15
Phosphoric acid (available)	10	05
Potash	10	05

This may seem an extreme case, but it is well within the facts, which may be ascertained by consulting the

bulletins on fertilizer analyses, as published by the different states.

Method of statement of guarantee sometimes misleading.

Guarantees, too, are sometimes rendered confusing to the purchaser because of the method of their statement, though the different methods used are, in one sense, entirely legitimate, because the terms used are in accordance with the facts. From a chemical standpoint, at any rate, it is quite as legitimate to guarantee the percentage of phosphoric acid equivalent to bone phosphate of lime, as it is to guarantee the percentage of actual phosphoric acid. It is because the consumer believes that the "equivalent" in combination means that he is obtaining something more than when actual constituents only are guaranteed, that he is led to purchase more freely, or to pay a higher price. Nitrogen may be properly stated in its equivalent of ammonia, phosphoric acid in its equivalent of bone phosphate, and potash in its equivalent of muriate of potash, and it is the business of the purchaser to understand the relations of the two methods of statement, in order that he may not be misled in his purchases. The following table shows the terms used, their equivalents, and the factor to use in multiplying, in order to convert the one into the other:

To convert the guarantee of			*Multiply by*
Ammonia	*into an equivalent of*	Nitrogen	0.8235
Nitrogen		Ammonia	1.214
Nitrate of soda		Nitrogen	0.1647
Bone phosphate		Phosphoric acid	0.458
Phosphoric acid		Bone phosphate	2.183
Muriate of potash		Actual potash	0.632
Actual potash		Muriate of potash	1.583
Sulfate of potash		Actual potash	0.54
Actual potash		Sulfate of potash	1.85

Discussion of guarantees.

It is shown in this table that, in order to convert ammonia into its equivalent of nitrogen, the percentage of ammonia should be multiplied by 82 per cent, or divided by the factor 1.214, because ammonia is 82 per cent nitrogen, and because one part of the nitrogen is equivalent to 1.214 parts of ammonia.

In order to determine the cost of a pound of nitrogen in dried blood, which is quoted, for example, at $3 a "unit," — 20 pounds of ammonia, — the unit 20 pounds is multiplied by 82 per cent, which gives 16.40 as the pounds of nitrogen offered for $3, or 18.3 cents a pound.

Bone phosphate of lime is, in round numbers, 46 per cent actual phosphoric acid. Hence, by multiplying the bone phosphate by 46 per cent, the percentage of actual phosphoric acid is obtained. Ground bone, for example, guaranteed to contain from 48 to 52 per cent bone phosphate, contains, in round numbers, 22 to 24 per cent of phosphoric acid. Sulfate of potash is 54 per cent, and muriate of potash is 63 per cent "actual" or potassium oxide, respectively. Hence, to convert the percentages of these forms into their equivalents of "actual," they are multiplied by the factors given.

In such raw materials as nitrate of soda, muriate of potash and sulfate of potash, a method of guaranteeing is used which is based upon their purity as chemical salts. That is, when pure they contain 100 per cent of the specific salt, and the guarantee accompanying the commercial product is simply a statement indicating their purity. For example, when nitrate of soda is guaranteed to con-

tain from 95 to 97 per cent pure nitrate, it means that it is 95 to 97 per cent pure, or that 3 to 5 per cent of the substance consists of impurities; it is not absolutely pure nitrate of soda. Hence, the minimum percentage of nitrogen guaranteed is 15.65 per cent, or 95 per cent of 16.47, the per cent or pounds in each hundred of nitrogen contained in pure nitrate of soda. When muriate of potash is guaranteed 80 per cent muriate, it means that 80 per cent of the salt consists of pure muriate of potash, and because pure muriate of potash contains 63 per cent of actual potash, or potassium oxide, the actual content of potash is derived by multiplying the 63 per cent, which the pure salt contains, by 80 per cent, and the result, 50.5 per cent, represents the amount of actual potash guaranteed. Sulfate of potash, high-grade, is usually guaranteed to be 98 per cent pure, and since pure sulfate of potash contains 54 per cent of actual potash, the content of actual potash, or potassium oxide, guaranteed is found by multiplying the 54 per cent by 98 per cent. The following illustrations show the two methods of stating the guarantees of raw materials and of mixed fertilizers:

Raw materials.

GUARANTEE ON BASIS OF PURITY

Nitrate of soda . . .	98%, or containing 98% pure nitrate
Muriate of potash . .	80%, or containing 80% pure muriate
Sulfate of potash . .	98%, or containing 98% pure sulfate
Kainit	25%, or containing 25% pure sulfate

GUARANTEE ON BASIS OF ACTUAL CONSTITUENTS

Nitrate of soda, total nitrogen	16.00%
Muriate of potash, actual potash	50.50%
Sulfate of potash, actual potash	53.00%

Mixed fertilizers.

GUARANTEE ON BASIS OF EQUIVALENTS IN COMBINATION

Nitrogen (equivalent to ammonia)	3 to 4%
Available phosphoric acid (equivalent to bone phosphate of lime)	18 to 22%
Potash (equivalent to sulfate of potash)	10 to 12%

GUARANTEE ON BASIS OF ACTUAL CONSTITUENTS

Nitrogen (total)	2.50 to 3.25%
Phosphoric acid (available)	8.00 to 10.00%
Potash (actual)	5.50 to 6.50%

The guarantees of the raw materials mean practically the same in the first as in the second case. In the first, the percentages given indicate the purity of the chemical salt; while in the second, the figures given indicate the actual content of the constituent contained in the chemical salt. In large commercial transactions, the sales are frequently made on the basis of certain purity percentages; as, for example, muriate of potash is sold at so much a ton on the basis of 80 per cent muriate. If the analysis shows it to contain less than 80 per cent, then the price paid per ton is less in proportion to such deficiency. If it is shown to contain more than 80 per cent, the purchaser pays for the excess at the same rate. In round numbers, a ton of muriate on the 80 per cent basis contains 1000 pounds of actual potash; if the price is $40 a ton, the cost a pound is 4 cents. If analysis shows but 900 pounds instead of 1000, the price paid a ton, at 4 cents a pound, is $36. If, on the other hand, it is shown to contain 1110 pounds, the price paid a ton is $44. Purchase made when this method of guaranteeing is used is practically equivalent to the "unit" basis, though, as

already stated, unless it is thoroughly understood, it is likely to be misleading.

What has been said of the different statements of guarantees of the raw materials, is also true in the case of the mixed goods. In the first, the percentages of the elements that are given represent the amounts when they exist in combination with other elements: nitrogen, as ammonia; phosphoric acid, as bone phosphate; and potash, as sulfate. While in the other, the percentages given indicate the content of the actual constituents; namely, nitrogen, phosphoric acid and potash.

The advantages and disadvantages of purchasing raw materials and mixed fertilizers.

In the purchase of fertilizers, therefore, two methods may be adopted: First, the buying of fertilizing materials, as distinct from fertilizers, which furnish single constituents like the standard high-grade products, or which furnish one or two of the constituents, like ground bone, tankage, fish and the miscellaneous products; these are called "incomplete," because they do not furnish all of the three essential constituents. Second, the purchase of the mixed manufactured brands, which contain all of the three essential constituents, nitrogen, phosphoric acid and potash, which are prepared to meet the demands of different soils and crops, and are called "complete," because containing all of the essential manurial constituents, or those liable to be lacking in any soil. The relative advantage of these different methods of purchase depends, first, upon the cost of the constituents, and second, upon the use that is to be made of them.

It may be urged that, on theoretical grounds, there are no good reasons why nitrate of soda, sulfate of am-

monia, dried blood, superphosphates and potash compounds should be mixed, as the manufacture of these does not improve or change the quality of the constituents — it consists chiefly in simply grinding, mixing and bagging. There are, however, advantages and disadvantages in both methods of purchase, the chief of which are stated below.

The advantages in the purchase and use of raw materials are:[1]

1. A better knowledge of the kind and quality of plant-food obtained. That is, these products as a rule possess characteristics which distinguish them from others and from each other, and they are more likely to be uniform in composition than mixtures.

2. It enables the use of one or more of the constituents as may be found necessary, thus avoiding the expense of purchasing and applying those not required for the particular crop or soil. The farmer is also enabled to adjust the forms and proportions of the various ingredients to suit what he has found to answer the needs of his soil or crop.

3. A saving in the cost of plant-food, since in their concentrated form, the expenses of handling, mixing and rebagging are avoided.

The chief disadvantages are:

1. The materials are not generally distributed among dealers, and thus not so readily obtained.

2. It is difficult to spread evenly and thinly products of so concentrated a character, particularly the chemical salts, which, unless great care is used, may injure by coming in immediate contact with the roots of plants.

3. The mechanical condition or degree of fineness is less perfect than in the manufactured products.

[1] "First Principles of Agriculture."

The advantages in the purchase and use of complete manures are:

1. They are generally distributed, and can be purchased in such amounts and at such times as are convenient.

2. The different materials may be well proportioned, both as to form of the constituents and their relative amount for the various crops.

3. The products are, as a rule, finely ground and well prepared for immediate use.

The chief disadvantages are:

1. That it is impossible to detect in a mixture whether the materials are what they are claimed to be.

2. That without a true knowledge of what constitutes value, many are led to purchase on the ton basis, without regard to the quantity and quality of the plant-food offered.

There is no question that the actual cost of the constituent is less when purchased in the fertilizing material than in the manufactured brand, as not only the expenses of mixing and bagging are saved, but the cost of handling the product per unit of plant-food is much less in the highly concentrated materials than in mixtures made up of both classes of fertilizing materials.

In the purchase of fertilizers by the second method, the cost of the constituents is not only higher on the average, but the variations in their cost are very much greater, due to the differences in the charges made by the different manufacturers for handling and selling their products.

HOME MIXTURES

The fact that fertilizing materials are a regular article of trade, and may be purchased as such, and the fact that

a complete fertilizer, so called, is really only a mixture of the various manufactured fertilizing materials, has suggested the use of what are called "home mixtures," — that is, their mixing by the farmer himself. This has proved to be very satisfactory under proper conditions, since, as already stated, the cost of the constituents is much less than if secured in the average manufactured brand (often from 25 to 50 per cent), and the mixing can be performed by the regular labor of the farm, and thus not add directly to the cost of the constituent.

This matter of home mixtures has been carefully studied by a number of the experiment stations, notably Connecticut, Rhode Island and New Jersey. The results of their studies are published in their regular reports, and show that the materials can be evenly mixed on the farm, that the mechanical condition is good and that the results obtained from their use are entirely satisfactory. It must be remembered, however, that whatever method of purchase is used, the object should be to obtain the kind and form of constituent best suited to the conditions under which they shall be used, at the lowest price a pound.

In any method of purchase which contemplates the use of a mixture, care should be taken in the selection of the brand or of the formula, since in mixtures as well as in the raw materials, there are two grades, the high-grade and the low-grade — high-grade in the sense that in quality the constituents are all good, and in the sense that maximum quantities are contained; and second, high-grade only in that constituents of good quality are furnished. They may be low-grade in the sense that both the quality and amount of constituents contained are low, and also in the sense that only the quality of the constituents is low, the quantity being sufficiently high.

Formulas.

The following formulas are used for the sole purpose of illustrating the differences that may exist between high-grade and low-grade mixtures, and not as indicating what should be used to make a good or poor mixture.

FORMULA No. 1

Amount Material	Pounds: Ammonia	Pounds: Phos. Acid	Pounds: Potash	Pounds: Plant-food	Price 100 Lbs.	Cost
500 lbs. nitrate of soda contains	80	—	—	80 costs	$2.50 =	$12.50
1100 lbs. acid phosphate contains	—	180	—	180 costs	.60 =	6.60
400 lbs. muriate of potash contains	—	—	200	200 costs	2.00 =	8.00
2000 lbs. mixture contains	80	180	200	460 and costs		$27.10
÷ 20 = 100 lbs. mixture contains	4.0	9.0	10.0	— and costs		1.355
Guaranteed composition	4.0	9.0	10.0	—		

FORMULA No. 2

Amount Material	Ammonia	Phos. Acid	Potash	Plant-food	Price 100 Lbs.	Cost
250 lbs. nitrate of soda contains	40	—	—	40 costs	$2.50 =	$6.25
1000 lbs. acid phosphate contains	—	160	—	160 costs	.60 =	6.00
80 lbs. muriate of potash contains	—	—	40	40 costs	2.00 =	1.60
670 lbs. make-weight or filler	—	—	—	—		
2000 lbs. mixture contains	40	160	40	240 and costs		$13.85
÷ 20 = 100 lbs. mixture contains	4.0	8.0	2.0	— and costs		.69
Guaranteed composition	4.0	8.0	2.0	—		

Formula No. 3

Amount Material	Pounds: Ammonia	Pounds: Phos. Acid	Pounds: Potash	Pounds: Plant-food	Price 100 Lbs.	Cost
600 lbs. tankage contains	30	90	—	120	costs $1.60 =	$9.60
400 lbs. kainit contains	—	—	50	50	costs .65 =	2.60
1000 lbs. make-weight contains	—	—	—	—		
2000 lbs. mixture contains	30	90	50	170	and costs	$12.20
÷ 20 = 100 lbs. mixture contains	1.5	4.5	2.5	8.5	and costs	.61
Guaranteed composition	1.5	4.5	2.5	—		

Formula No. 4

Amount Material	Ammonia	Phos. Acid	Potash	Plant-food	Price 100 Lbs.	Cost
1200 lbs. tankage contains	60	180	—	240	costs $1.60 =	$19.20
800 lbs. kainit contains	—	—	100	100	costs .65 =	5.20
2000 lbs. mixture contains	60	180	100	340	and costs	$24.40
÷ 20 = 100 lbs. mixture contains	3.0	9.0	5.0	17.0	and costs	1.22
Guaranteed composition	3.0	9.0	5.0			

Formula No. 1 shows a high-grade product, both in respect to quality of plant-food and concentration, while No. 2 is high-grade only in respect to quality. In order that the plant-food may be distributed throughout a ton of material, it is necessary to add what is called "make-weight," or a diluent. These usually consist of substances that possess no direct fertilizing value. High-grade mixtures cannot be made from low-grade materials, and

low-grade mixtures cannot be made from high-grade materials without adding "make-weight." The advantages of high-grade products are concentration and high quality of plant-food.

It will be observed that formula No. 1 contains nearly twice as much plant-food as No. 2, or, in other words, it will require about two tons of a fertilizer made according to formula No. 2 to secure the same total amount of plant-food as is contained in one ton of No. 1. Now, the material in No. 2, other than the actual plant-food, is of no direct fertilizing value, — it is of no more value as a fertilizer than the soil to which it is applied, — but the actual cost of the constituents is considerably increased, because the expenses of handling, bagging and shipping are just double what they would be for No. 1.

Formula No. 3 illustrates a low-grade fertilizer in the sense that it contains the poorer forms of the constituents, and furnishes a comparatively small total amount of plant-food. The nitrogen is all in the organic form, and is derived from tankage, which, while not the poorest, is poorer than other forms of organic nitrogen. The phosphoric acid is also in organic combination, and, while useful under many conditions, is less useful for certain other conditions than the soluble in Nos. 1 and 2. The potash, while soluble, is derived from kainit, which, because of its large content of chlorin, is regarded as less desirable for certain crops than the more concentrated materials, muriate, or the high-grade sulfate, which is free from chlorids. It would require more than $2\frac{1}{2}$ tons of a mixture made according to this formula to furnish as much total plant-food as would be contained in a mixture made according to formula No. 1, besides the disadvantage of the lower quality of the constituents.

Formula No. 4 illustrates a mixture which, while rich in total constituents, is not high-grade in its quality.

All of these considerations should therefore be carefully observed in the purchase of mixtures, or even in the purchase of raw materials for home mixtures, and the analysis, if properly made, will give positive evidence on these points.

The expensiveness of low-grade fertilizers, as represented by formulas Nos. 2 and 3, is not fully appreciated by the purchaser in all cases. He does not stop to think that it is quite as expensive to handle the material which contains no plant-food as it is to handle material which is rich in plant-food.

The cost of handling "make-weight."

A comparison of the advantages of low-grade and high-grade mixtures in this sense of total quantity of plant-food may be illustrated as follows:

It has been shown by continued studies at the New Jersey Experiment Station that the charges of the manufacturers and dealers for mixing, bagging, shipping and other expenses are, on the average, $8.50 a ton; and also that the average manufactured fertilizer contains about 300 pounds of actual fertilizing constituents to a ton. A careful study of the fertilizer trade indicates that these conditions are also practically true for other states in which large quantities of commercial fertilizers are used.

A mixture of formula No. 1 would contain 460 pounds of actual available fertilizing constituents in each ton — 160 pounds, or over 50 per cent more than is contained in the average manufactured brand. That is, a farmer purchasing a brand similar to formula No. 1 would secure in 2 tons as much plant-food as would be contained in

3 tons of the average manufactured brand. Assuming that the charges per pound of plant-food at the factory, and the expense charges, are the same in each case, and also that the quality of plant-food in the one is as good as in the other, the consumer would save $8.50 by purchasing 2 tons of the former instead of 3 tons of the latter. In a few states the consumption of fertilizers reaches nearly 100,000 tons annually, while in many it ranges from 30,000 to 50,000 tons.

Thus is shown the very great saving that may be effected in the matter of the purchase of fertilizers from the standpoint of concentration alone, or, in other words, the importance of a definite knowledge of what constitutes value in a fertilizer. This saving may be accomplished, too, without any detriment to the manufacturer, since the difference to him between making high-grade or low-grade goods, in reference to concentration, is largely a matter of unskilled labor. The manufacturers are in the business to cater to the demands of the trade. If consumers are intelligent, high-grade rather than low-grade goods will be provided by the manufacturers. Furthermore, as already indicated, high-grade in the matter of concentration means high-grade in quality, for high-grade mixtures cannot be made from low-grade products.

GENERAL ADVICE

As farmers understand more fully the question of fertilization, and as intensive methods of practice are adopted, the tendency in the purchase of fertilizers will undoubtedly be toward the first method, or the purchase of fertilizing materials, rather than mixtures, or at any rate, of high-grade special mixtures, rather than what

are now termed "standard brands," which are, as a rule, low-grade in the concentrated sense. This tendency will come, first, because intensive practice requires a larger use of all of the constituents, and second, a greater need in the growth of certain crops of specific or dominant elements, and thus better results are obtained from the application of single constituents, or the use of special formulas, than in "extensive" practice, in which the object is more to supplement the soil supplies than to fully provide for all the needs of the plants for food.

The tendency toward coöperative buying on the part of small farmers will increase as it has done in those countries in which there is a larger use of fertilizers than here, though the method is already in successful operation in certain sections of the country, and with very gratifying results. In this method of direct purchase, the manufacturer and the consumer are brought into closer relations with each other. Transactions are based upon the transfer of a definite number of pounds of a specific kind and form of plant-food, rather than upon some mysteriously remarkable qualities that are claimed, and are by many supposed to be inherent in certain mixtures.

CHAPTER X

CHEMICAL ANALYSES OF FERTILIZERS

A COMPLETE chemical analysis of a fertilizer shows not only the total amount of the different constituents contained in a brand, but the form in which they exist, and in most cases, the source of the materials used is also indicated.

THE INTERPRETATION OF AN ANALYSIS

An analysis may show simply the total amount of the constituents. This is not a sufficient guide as to the value of a mixture, for while it is not possible to indicate absolutely by analysis whether the organic nitrogen, for example, is derived from blood (which is one of the best forms), or from horn meal (one of the poorer forms), it is possible to show whether the nitrogen is derived from nitrate or from ammonia, whether the phosphoric acid is derived from a superphosphate or a phosphate, and whether the potash present is in the form of a sulfate or of a muriate. A high-grade or a low-grade fertilizer, for example, may be distinctly indicated by the analysis, since it is of a high-grade if the three forms of nitrogen are present, if the total phosphoric acid is chiefly soluble in water, and if the potash has been derived from a sulfate or from a muriate. On the other hand, if the analysis shows

that the nitrogen is all in the organic form, that only a minimum percentage of the phosphoric acid is available, though not soluble, and that a high content of chlorin accompanies the potash, it is a low-grade product, in so far as the form of the constituents is concerned. The following statements of analyses of two brands, showing the same total content of constituents, illustrate this point:

ANALYSIS No. 1

Nitrogen, as nitrate	1%	
Nitrogen, as ammonia	1%	
Nitrogen, as organic matter	1%	
Total		3%
Phosphoric acid, soluble	8%	
Phosphoric acid, reverted	1%	
Phosphoric acid, insoluble	1%	
Total available		9%
Potash		5%
Chlorin		0.50%

ANALYSIS No. 2

Nitrogen, as nitrate		
Nitrogen, as ammonia		
Nitrogen, as organic matter	3%	
Total		3%
Phosphoric acid, soluble		
Phosphoric acid, reverted	2%	
Phosphoric acid, insoluble	8%	
Total available		2%
Potash		5%
Chlorin		10%

A study of these two statements of analyses shows that the total contents of the constituents are identical, 3, 10 and 5, respectively, in each case. That is, so far as the total amounts are concerned, one brand furnishes as much as the other, and from that standpoint

alone it is as good as the other; but it has been already shown that the value of a fertilizer depends not only upon the total content of its constituents, but upon the form in which they exist. In the first brand it is found that two-thirds of the total nitrogen exists in the soluble form, equally divided between nitrate and ammonia; the remaining third is in the organic form, and may be derived from blood, or from some low-grade materials. It is to be fairly presumed, however, that when thus associated with so high a proportion of soluble nitrogen, it is in a good form, as the manufacturer has given evidence of his intent by his liberal use of other good forms.

In the case of the phosphoric acid, it is shown that of every 100 pounds of the total, 80 pounds are soluble, 10 reverted, or nine-tenths of the whole is available; 10 pounds of every hundred only are insoluble, which is not only an indication, but positive proof, that the phosphoric acid is derived from a superphosphate.

In the case of potash, the chlorin associated with it is but ½ per cent, indicating that it has been drawn from high-grade sulfate, since kainit and muriate are rich in chlorin, while in a high-grade sulfate no appreciable amounts of chlorin are present.

In the second statement, all of the nitrogen is shown to be in the form of organic matter. It may be derived from blood, though it is not likely to have been drawn from this source, since of the total phosphoric acid but 20 pounds to the hundred, or one-fifth, is available, and that is reverted rather than soluble, indicating that the phosphoric acid must have been drawn from tankage or from bone, or other materials which contain reverted but no soluble phosphoric acid, and which also contain a considerable percentage of nitrogen. The phosphoric acid

was certainly not drawn from a superphosphate, or it would have shown a higher percentage of available, a certain proportion of which whould have been soluble, and the percentage of insoluble would have been very much less. In the case of potash, it is quite evident that it was drawn from kainit, inasmuch as the percentage of chlorin exceeds the percentage of the potash, as would be the case if the potash had been drawn from that source.

Thus it is that a complete chemical analysis of a fertilizer indicates very clearly the source of the materials by the form in which the constituents exist in the mixture.

THE AGRICULTURAL VALUE OF A FERTILIZER

It is obvious, from what has already been pointed out, that the value of a fertilizer to the farmer depends not so much upon what is paid for it as upon the character of the materials used to make it. This value is termed the "agricultural value," and it is measured by the value of the increased crop produced by its use. It is, therefore, a variable factor, depending first, upon the availability of its constituents, and second, upon the value of the increased crop produced.

For example, in the first place, the agricultural value of a pound of soluble phosphoric acid is likely to be greater than that of a pound of insoluble when applied under the same conditions as to soil and crop, because in the one case the element is in its most available form, while in the other it is least available. In the second place, the soluble phosphoric acid may exert its full effect and cause a greatly increased yield on a certain crop, and still not cause an increase in its value sufficient to pay the cost of the application, while for another crop the same applica-

PLATE VIII. — Wheat and Timothy.

FIG. 15. — THIRTY-FIVE BUSHELS OF WHEAT TO THE ACRE, MECHANICSBURG, PENNSYLVANIA.

FIG. 16. — EARLY SPRING TOP-DRESSING WITH COMMERCIAL FERTILIZER HIGH IN AVAILABLE NITROGEN GREATLY INCREASES THE YIELD OF TIMOTHY.

tion may result in a very great increase in the value of the crop. The character or form of the materials used in a mixture, as well as their suitability for the crop must, therefore, be carefully considered in the purchase of fertilizers. Slow-acting materials cannot be expected to give profitable returns, particularly upon quick-growing crops, nor expensive materials such profitable returns, when used for crops of relatively low value, as for crops of relatively high value.

THE COMMERCIAL VALUE OF A FERTILIZER

This agricultural value, however, is separate and distinct from what is termed "commercial value," or cost in market. This value is determined by market and trade conditions, as the cost of production of the crude materials and the cost of their manufacture and sale. Since there is no strict relation between agricultural and commercial or market value of a fertilizer constituent, it frequently happens that an element in its most available form, and under ordinary conditions of high agricultural value, costs less in market than the same element in less available forms and of a lower agricultural value. The cost of production in the one case is lower than in the other, though the returns in the field are far superior.

It is manifestly impossible to fix an agricultural value for any of the constituents that will be true under the varying conditions of soil, crop and season, and method of use, though the relative value of the different forms under uniform conditions of use may be fairly indicated, and the analysis is the guide as to their form. The commercial value of the different constituents in their various forms

may, too, be fairly indicated, and will vary according to variations in trade conditions. If the wholesale jobbing price of nitrogen as nitrate is 15 cents a pound, available phosphoric acid 5 cents a pound, and potash 4 cents a pound, these are the prices which the manufacturers pay. Their increased cost in manufactured brands, therefore, is in proportion to the cost of this work; hence their cost to the consumer at factory should vary within reasonably narrow limits, due to variations in cost of manufacturing in different localities.

An illustration of the commercial value is shown by the following example: Suppose that nitrate of soda costs, or can be purchased at retail, in ton lots, for $48 a ton, which is, then, its commercial value. The commercial or trade value of the nitrogen is, therefore, 15 cents a pound, since a ton contains on the average 320 pounds of nitrogen. Or, suppose that the retail price of available phosphoric acid in superphosphates is $1 a unit; this is its commercial value, and hence the commercial or trade value of the available phosphoric acid would be 5 cents a pound, since a unit contains 20 pounds. It does not follow that the application of a pound of nitrogen costing 15 cents, and therefore having a commercial value of 15 cents, will result in an increased crop worth 15 cents, or that the application of a pound of phosphoric acid costing 5 cents a pound will result in an increased crop worth 5 cents. The increased returns in crop from their use may be very much greater or much less than the cost of the constituents, depending upon the kind of crop and the skill of the user. In the purchase of materials, however, a commercial valuation is a guide as to the cost of the constituents from different manufacturers or dealers; and in many states a system of commercial values for

mixed fertilizers has been fixed, which, when properly understood, is a useful method of comparison of the different brands.

This method is based upon the fact that at points of supply a pound of nitrogen, in the form of nitrate, of ammonia or of definite organic compounds, or a pound of available phosphoric acid, or of potash in the form of muriate or sulfate, is practically the same to all manufacturers. That is, these cost prices, or trade values, when applied to the constituents in the mixture, represent their commercial value before they are mixed to form complete fertilizers. Hence, the difference between the valuation of a brand on this basis and the cost to the consumer represents the charges, including profit, for mixing, bagging, shipping and selling the goods.

The commercial or trade value for each of these constituents is obtained, as already indicated, by simply calculating the cost, using two factors, — the wholesale prices for the different materials containing them, and their average composition. To this cost is added a certain percentage, to represent the cost of handling and distribution in small lots. Thus the trade value corresponds as nearly as may be with the cost of the constituents to the farmer. That is, the price fixed represents what the farmer would have to pay the manufacturer for the constituents in the material before it is mixed.

For example, suppose the wholesale price a ton of nitrate of soda for the six months preceding March 1 is shown to be $40; the wholesale cost of nitrogen in this form is, therefore, 12.5 cents a pound. To this wholesale price may be added a certain sum to cover the expenses of handling, usually 20 per cent, thus making the retail price a ton $48, and the trade or commercial value of the

nitrogen 15 cents a pound. That is, the $48 a ton, or 15 cents a pound, represents the retail cost a pound of nitrate nitrogen. This, if applied to the nitrogen as nitrate, in the mixed fertilizer, will show what it could have been bought for as nitrate in the unmixed fertilizer. The values for the other constituents are derived in the same way. These, together, make the schedule of trade or commercial values of the constituents which are used in the computing of the commercial values of mixed fertilizers. The schedule of values is revised annually, and, as nearly as possible, at the same time in the year. The following schedule, used as an illustration of this point, was adopted by the Directors and Chemists of the Experiment Stations of New Jersey and the New England states for use in that territory for the year 1914:

Schedule of Trade Values	Cents per pound
Nitrogen in nitrates	16.5
Nitrogen in ammonia salts	16.5
Organic nitrogen in fine [1] ground fish, meat and blood	22.5
Organic nitrogen in cotton-seed meal and castor pomace	22.5
Organic nitrogen in fine [1] bone and tankage	21.5
Organic nitrogen in mixed fertilizers	19.5
Organic nitrogen in coarse [1] bone and tankage	17.5
Phosphoric acid, soluble in water	4.5
Phosphoric acid, soluble in ammonium citrate	4.0
Phosphoric acid in fine [1] bone and tankage	4.0
Phosphoric acid in cotton-seed meal and castor pomace	4.0
Phosphoric acid in coarse [1] bone, tankage and ashes	3.5
Phosphoric acid, insoluble in water and in ammonium citrate	2.0
Potash in high-grade sulfate, and in the forms free from muriate (chlorids)	5.0
Potash in muriate	4.0
Potash in cotton-seed meal and castor pomace	5.0

[1] "Fine" signifies such as will pass through a sieve with circular holes $\frac{1}{50}$ of an inch in diameter, and "coarse" such as will not.

It will be observed that the schedule gives the cost a pound of the different forms of nitrogen, and of high-grade organic nitrogenous materials; of nitrogen and phosphoric acid in ground bone and tankage; of available phosphoric acid in superphosphates, and of actual potash in the potash salts, and is a useful guide also in showing that the nitrogen, phosphoric acid and potash contained in these materials can be purchased in ton lots for the prices mentioned. *The valuations of mixed fertilizers, obtained by the use of this schedule, are entirely commercial; they are not intended to indicate even a possible agricultural value.* This point needs to be emphasized, as many are inclined to interpret them as not only guides as to agricultural value, but as positive statements of such value. It can be said, however, that those who do so do not familiarize themselves with the discussions that usually accompany reports of analyses. The different trade values given for the nitrogen and phosphoric acid in the two grades of bone represent their value in the form of ground bone and of bone meal, products which are distinctly recognized in the market, and which are quoted at different prices. The coarser ground bone is lower in price than the finer bone meal.

The accuracy of the schedule of values can be shown by comparing it with the actual prices paid for the constituents in the different materials, and such comparisons as have been made from year to year, by a number of the institutions exercising an analysis control, show that manufacturers and dealers are willing to sell to farmers at prices corresponding very closely with the schedule.[1]

A value is placed upon the insoluble phosphoric acid

[1] See Bulletins Connecticut and New Jersey Experiment Stations.

in mixed fertilizers, not because all insoluble costs the price given, but because in mixtures it is assumed that the phosphoric acid is drawn from organic sources, which do cost, at least, the price given.

There are arguments both in favor of and in opposition to this method of comparing the commercial values of mixed fertilizers. The chief arguments in opposition may be stated as follows:

First, that the prices of these materials vary, and hence in order to represent the actual commercial value at the time the sales are made, they should be changed as the markets change.

Second, the valuations are misleading, because the farmer does not clearly understand their meaning, and is thus guided in his judgment of the usefulness or agricultural value of a fertilizer by the stated commercial value, as shown by this method, rather than by the kind, form and proportion of constituents that may be contained in it, and upon which its agricultural value should be based.

Third, the chemical analysis does not show absolutely the sources of the materials, and thus it is difficult to place a true commercial value upon a mixture. This is especially true of organic nitrogen, since because it is impossible to separate the amounts that may be derived from different materials, a uniform value is placed upon the total nitrogen found, whether it is derived from the best forms, as dried blood and dried meat, or whether derived from horn meal, ground leather or other low-grade forms of nitrogenous material. This encourages the use of low-grade products by unscrupulous manufacturers, to the real detriment of the trade as a whole.

Fourth, that the commercial value so fixed militates

against the use of certain kinds of good materials, and in favor of certain kinds of poorer materials. That is, a valuation of 2 cents a pound for insoluble phosphoric acid in complete fertilizers, for example, is a direct encouragement to include in the mixture a considerable proportion of the insoluble phosphoric acid from South Carolina, and other rock phosphates, the value of which is ignored in commercial transactions; while that price (2 cents) does not give a fair value to the phosphoric acid contained in bone, tankage and natural guanos, products in which the commercial value of the insoluble is recognized, — that is, mixtures which contain bone and tankage, and which furnish phosphoric acid largely in an insoluble form. The valuation fixed for this form is too low to fully represent the commercial value of these goods. It is also said that the trade value for available phosphoric acid in the mixtures encourages the use of superphosphates from the rock phosphates, and discourages the use of superphosphates from bone-black, bone-ash and dissolved bone, because the trade or commercial values represent the average cost of available phosphoric acid in the superphosphates from all of these, while the latter materials, because of actual commercial conditions, cost more than the superphosphates from the former.

The chief arguments in favor are:

First, that it is not asserted that the system shows absolutely the commercial value of each brand at the time the sales are made, but the comparative commercial value.

Second. They are not misleading. The commercial valuations are not intended to be a guide as to the agricultural value of a fertilizer. It is distinctly stated in the reports of analyses that the comparative values are purely commercial.

Third. It is a system which more nearly approaches perfection than any other that has been devised, is educative in its tendency, and is a safe guide, in the majority of instances, as to the charges made for mixing, handling and selling plant-food contained in the different brands. If the analysis is properly interpreted, as already indicated, it is the purchaser's fault if he buys poor forms of plant-food at a high price. It is certainly a safer guide than mere name of brand, and does not encourage the use of poor materials.

Fourth. Any system of comparison of brands must leave a great deal to the judgment of the purchaser. He must interpret for himself whether he would rather that his phosphoric acid were derived from one source or another, whether he would prefer to pay a higher price for insoluble phosphoric acid in acid phosphate, and have the remainder soluble, than to pay the same or a greater price for the insoluble phosphoric acid in bone, and have the remainder of it in the reverted form. These conditions are again indicated by the analysis which accompanies the valuation; the valuations are, therefore, not to be used in total disregard of the composition. If they are so used, it is not the fault of the system. That it militates against the use of high-priced superphosphates, if they are no better than the lower-priced ones, is no argument against the system, but rather for it, since it tends toward a readjustment of the prices, a condition that must be met in all competitive trades. Furthermore, the valuation system has been effective in driving out materials that are either fraudulent in their character or of very low-grade. It is impossible to obtain a high valuation on poor materials, and in the majority of cases dependence upon valuations alone would be a safe guide

as to the comparative agricultural value of brands of the same general composition.

CALCULATION OF COMMERCIAL VALUES

The following examples illustrate how commercial values of complete fertilizers and of ground bone are calculated. The mixed, or complete, fertilizer contains the three forms of nitrogen, three of phosphoric acid, and the two forms of potash. In the bone, it is assumed that 50 per cent of the meal is finer than 1-50 inch, and is, therefore, regarded as fine, and that 50 per cent is coarser than 1-50 inch, and is, therefore, regarded as coarse; and it is also assumed that the proportions of the nitrogen and phosphoric acid in the fine and coarse is the same; also, that the analysis shows the bone to contain 4 per cent of nitrogen and 20 per cent of phosphoric acid:

A COMPLETE FERTILIZER

	1	2	3	4
	% or lbs. per 100	*Lbs. per ton*	*Value per lb. cts.*	*Estimated value per ton of each constituent*
Nitrogen, as nitrates	1 × 20 =	20 ×	16.5 =	$3.30
Nitrogen, as ammonia salts .	1 × 20 =	20 ×	16.5 =	3.30
Nitrogen, as organic matter .	1 × 20 =	20 ×	19.5 =	3.90
Phosphoric acid, soluble . .	8 × 20 =	160 ×	4.5 =	7.20
Phosphoric acid, reverted . .	1 × 20 =	20 ×	4.0 =	.80
Phosphoric acid, insoluble . .	1 × 20 =	20 ×	2.0 =	.40
Potash, as muriate	5 × 20 =	100 ×	4.0 =	4.00
Potash, as sulphate	5 × 20 =	100 ×	5.0 =	5.00
Total estimated value per ton				$26.90

The first column shows the percentage of the constituents contained, which, multiplied by 20, gives the pounds per ton in the second column, which, multiplied

by the schedule prices a pound, gives the valuation per ton, as shown in the fourth column.

GROUND BONE

	1	2	3		4	5	6
	% or lbs. per 100	*% of fineness*	*% or lbs. per 100*		*Lbs. per ton*	*Value per lb. cts.*	*Estimated value per ton*
Nitrogen . .	4 ×	50 =	2 in fine	× 20 =	40 ×	21.5 =	$8.60
	4 ×	50 =	2 in coarse	× 20 =	40 ×	17.5 =	7.00
Phosphoric acid . .	20 ×	50 =	10 in fine	× 20 =	200 ×	4.0 =	8.00
	20 ×	50 =	10 in coarse	× 20 =	200 ×	3.5 =	7.00
Total estimated value a ton							$30.60

The first column of figures shows the per cent, or pounds per hundred, of the constituents, which is multiplied by the percentage of fineness, which gives the percentage or pounds to the hundred of fine or coarse in the third column. The calculation is then finished as in the case of complete fertilizers.

THE UNIFORMITY OF MANUFACTURED BRANDS

Another point which consumers of fertilizers are interested in is the reliability of the various brands. That is, they desire to know whether a brand that shows good forms of nitrogen, of phosphoric acid, and of potash in one year may be depended upon to furnish approximately the same the following year, or whether the manufacturers change their formulas from year to year to conform to the relative cost of the different materials; that is, whether when nitrogen is relatively expensive and phosphoric acid is relatively cheap, they introduce a larger proportion of phosphoric acid and a smaller percentage of nitrogen; whether when organic nitrogen is cheap and nitrate and

ammonia nitrogen are dear, they change the proportions of these to correspond with the difference in price, in order to retain the same selling price.

This is an important point, since after a certain brand has been shown to be better suited than another to their conditions of soil, to change the formula, both in reference to the character and proportions, may mean to the purchaser the difference between profit and loss.

Evidence on this point can be obtained from the reports showing the results of the analyses of the different brands from year to year, and a careful study of these shows that genuine manufacturers of fertilizers — those who make it their sole business, rather than a side issue or an adjunct to another business — can be fully depended upon in this respect. They know that the farmer's interest is their interest, and that their sales will depend, other things being equal, upon the increased crop results that the farmer secures; that the permanency and success of their business will depend upon the successful and profitable use of their product; and that they cannot afford to and do not change their formulas from year to year, either in proportion or quality of constituents, to correspond with the changes in price of the materials. Their brands can be depended upon to furnish practically the same amount, kind and proportion of plant-food from year to year.

The value of a fertilizer depends upon the kind, quality and form of plant-food, as shown by the analysis. Value does not depend upon who the manufacturer is, or what the statements may be concerning the usefulness of special manipulation, nor to any great extent upon special formulas, unless the farmer has positive knowledge of the character of his own conditions. Formulas derived both in

kind and proportion from the same materials will do equally well under the same conditions. So far as the matter has been investigated, there is no specific virtue added by what is claimed to be the "blending" of the materials.

In the whole matter of the purchase of fertilizers, no guide, however good, can take the place of intelligence on the part of the purchaser. This intelligence must be exercised in the selection of forms of plant-food, in the preparation of formulas, in the interpretation of guarantees and of commercial values, and in the method of using the fertilizer.

CHAPTER XI

METHODS OF USE OF FERTILIZERS

The primary object in the use of a commercial fertilizer is to receive a profit from the increase in the yield of crops from the land to which it is applied; and this may be derived either from the immediate crop, or from the larger yield of a number of crops. That the greatest immediate or prospective profit may be gained, a wide knowledge of conditions which have either a direct or indirect bearing upon the result is essential.

CONDITIONS WHICH MODIFY THE USEFULNESS OF FERTILIZERS

In fact, the controlling conditions surrounding the matter are so numerous and so various that it is impossible, with our present knowledge, to lay down positive rules for our guidance. At best, only suggestions can be offered.

We may possess a full knowledge of both the kind and form of existing fertilizer supplies, their cost and the action under known conditions of the constituents contained in each, as well as their maximum capability for increasing the crop, but together with this knowledge, it is essential that we should know how these facts and principles must be applied to each individual crop, soil and condition, and yet even with this, absolute certainty of profit is not guaranteed. A few of the more important conditions

which control the profitable use of fertilizers are, therefore, briefly discussed, in order to arrive at a better understanding of the practical suggestions and concrete examples given in subsequent chapters.

Derivation of soil a guide as to its possible deficiencies.

The first consideration is the soil itself, and its influence. It is well known that a wide difference exists in soils, both in reference to their chemical character or composition, and to their physical properties, each having a direct influence in determining the effect of any specific application of fertilizers. These differences in soils are due to changes which were wrought in the surface of the earth during its formation, and which are continuing in a small way at the present time. It is believed that the original earth crust contained all the minerals now found in it, but that in the beginning they were distributed more uniformly throughout its mass, and that the soils as they exist at the present time, and as a result of the direct disintegration of the original rock, represent a very small area of the earth's surface. They are not now constant, but variable in their character. The various changes that have taken place during geologic time have resulted in the breaking up of the original rocks, a part having been separated mechanically and being represented by various sizes of particles, and a part rendered soluble. The fragments and the soluble portions thus separated have not been deposited again in the same proportions as they existed in the original rock, which has caused a very wide variation in the chemical composition of the different soil deposits. The process and its results may be shown at the present time in the wearing away of rocks. The harder, sandy particles separate mechanically, and because of the difference in the

size of the particles, the coarser are deposited as gravel or sand, in one place, and the finer particles are deposited in another, making the clay. The lime enters partly into solution and is deposited in another place, and so on, thus giving us sandy soils, clayey soils and limy soils, all differing from each other in their amount and proportion of the essential fertilizing constituents, as well as in their physical qualities, — the sandy and gravelly making the poorest soils because the particles consist very largely of quartz, and the remainder being poor in phosphoric acid or potash. The clay soils are frequently rich in minerals containing potash, and poor in those containing lime and phosphoric acid; and the limestone soils are poor in potash and rich in lime, and frequently in phosphates. In addition to these soils, there are those that are made up largely of vegetable matter, due to the accumulation of decaying growths. These are frequently rich in nitrogen and poor in all of the essential mineral constituents.

Hence it is that in the use of a commercial fertilizer, at least for certain crops, a knowledge of the nature of soils in respect to the possible deficient element is important, in order that those which exist in abundance may not be added to, but that they may be supplemented by such an abundance of the deficient elements as to permit the acquirement by the crops of those necessary for a maximum growth. As a rule, potash is a very essential constituent of manures for sandy soils, not only because all crops require potash, but because they require it in relatively large amounts, and because in sandy soils it is liable to exist in minimum amounts. Potash fertilization, therefore, is especially useful on sandy soils. On the other hand, in clay soils, which, as a rule, contain a very considerable proportion of potash as compared with sandy soils, the

deficient element may be either phosphoric acid or lime; and if these are supplied in abundance, the plant will be able to secure the necessary potash. In a limy soil, the lime and phosphoric acid, and perhaps the potash, may be in sufficient abundance to cause a normal growth of plant, yet the nitrogen may be so deficient as to prevent a normal growth.

Physical imperfections of sandy soils.

If it were possible distinctly to classify soils in respect to their lack of one or more of the essential constituents, it would be an easy matter to formulate rules for our guidance in the fertilization of these soils; but such is not the case. Even sandy soils vary widely in their chemical composition, as well as in their mechanical or physical properties, and certain of them possess such a physical character as to make it impossible to grow maximum crops even though the essential elements are all supplied in sufficient abundance. The constituent particles are too coarse, and thus make the soils so open and porous that they too freely admit the air, water and warmth, and thus results a very rapid drying and heating of the soil, with a premature ripening and burning of the crops. The phosphates or the potash compounds applied are not readily fixed, and suffer an immediate loss as soon as rain falls in such amounts as to cause a leaching from them.

Physical imperfections of clay soils.

In clay soils, the physical conditions are quite the reverse. All clay soils do not have the same general composition, and they differ widely in their physical qualities. Certain of them possess a reasonably good texture, and permit the absorption of the food applied, as well as its gradual dis-

tribution throughout the mass by the percolation of the water through them; while certain others are so compact, owing to the finely divided particles, that even though they were abundantly supplied with all of the necessary mineral constituents, profitable crops could not be grown because the roots could not readily penetrate, and because the water falling upon the land would not readily pass through, but remain upon the surface.

In the case of soils with an abundance of lime, physical qualities also exercise a very considerable influence, even though there is a sufficient supply of all of the fertility elements. Certain of them are too cold, others are too dry, and the mechanical condition is such as to prevent the proper and uniform growth of plants. It must be remembered, then, that only general rules apply in the use of fertilizers upon soils of the different classes, and that they are modified by both the chemical composition and the mechanical condition of the soils. The best use of a fertilizer — that is, the greatest proportionate return of plant-food in the crop, all things considered — is obtained from its application upon soils that possess "condition," or that are well cultivated or managed. Full returns cannot be expected when they are applied upon soils that are too wet or too dry, too porous or too compact, or too coarse or too fine. It is important that even the best soils should be properly prepared, and it is infinitely more important that those which possess poor mechanical condition should be improved in this respect, before large expenditures are made for fertilizers.

The influence of previous treatment and cropping.

In the next place, the previous treatment and cropping of soils should guide in the use of fertilizers, since soils of

the same natural character, located equally well, will not always show the same results from the application of fertilizers, because in the one case the cropping has been such as to result in the rapid exhaustion of one, rather than the three specific fertilizer elements; while in the other, the cropping may have been quite as severe, but has been helpful because judicious rotations have been used and improved methods practiced. It may be that in the one case, there may have been a continuous cropping of wheat, for example, and only the grain sold from the farm, in which case there would be a much more rapid exhaustion of the nitrogen and phosphoric acid than of the potash; and if this continuous wheat-cropping has been continued for a long time, an application of the phosphates only may result in quite as large an increase in crop as if both phosphates and potash salts were applied, because the potash exhaustion has been less rapid than that of the phosphoric acid, and the addition of potash would simply add to the probably abundant quantities already there. On the other hand, if the cropping has been timothy hay, the removal of the potash would have been greatly in excess of the phosphoric acid, and consequently a fertilization with a greater proportion of potash, or even this element alone, of the minerals, may result in quite as large returns as if the fertilization had consisted of both phosphoric acid and potash. In fact, if the land had been cropped continuously with tobacco, cotton, potatoes or other crop, there is likely to be a much larger removal proportionately of some one element, rather than proportionate amounts of all. This practice results in a disproportionate removal of the constituents, and in order to bring the land back to its capacity for maximum production, or to equalize matters in this respect, it is necessary to add to the soil the constituents

removed in amounts in excess of the others. On the other hand, the cropping may have been such as to be fully as exhaustive in the sense that the total quantity of constituents removed is quite as great, though since they are removed in more uniform proportions, the period of profitable cropping is extended, and the fertility needed includes all the essential elements, rather than one or two. That is, the grain, hay and potatoes may have been grown in rotation, each removing one or the other in greater proportion, but because they differ with each crop, no one is exhausted before the other; and thus when the land reaches the time when it would no longer profitably grow those crops, an application then of all of the constituent elements would result in a greater and more profitable increase in crop than if the fertilizer contained one constituent only. The previous treatment and cropping of soils, therefore, is an important guide in determining the most economical method of fertilization.

Furthermore, in this matter of cropping as a guide to possible need of fertilization, it must be remembered that a continuous one-crop practice is more productive of total loss of constituents than a practice which includes such renovating crops as clover, or one which permits of a more constant occupation of the land, since in the former, the introduction of clover reduces the need for nitrogen fertilization, and in the latter, the vegetable matter is not so rapidly used up, and the loss of mineral constituents by mechanical and other means is very much reduced, because of the constant occupation of the land.

The influence of character of crop.

The financial result from the application of fertilizers is also influenced in a very large degree by the character

of the crop itself, whether the value of an increase in crop as great as can be expected from a definite application is high or low; and on this basis, crops may be classified into two general groups: first, those which possess a high fertility, and which, as a rule, possess a relatively low commercial value; and second, those which possess a low fertility value and a relatively high commercial value. In the first class are included the cereal and forage crops, as corn, oats, wheat, hay, buckwheat, cotton and tobacco, and in the second are included the various vegetable and fruit crops. This classification, and its importance, may be illustrated by the following examples:

A ton of wheat, at $1 a bushel, will bring $33.33. Its sale removes from the farm 38 pounds of nitrogen, 19 of phosphoric acid and 13 of potash. At prevailing prices for these constituents, it would cost $6.50 to return them to the farm.

A ton of asparagus shoots, at 10 cents a pound bunch, will bring $200. Its sale removes from the farm 6 pounds of nitrogen, 2 of phosphoric acid and 6 of potash, which could be returned for but little more than $1.

A ton of timothy hay will bring $14. Its sale removes from the farm 18 pounds of nitrogen, 7 of phosphoric acid and 28 of potash, amounts that would cost $4.

A ton of apples will bring in an ordinary season $20. It removes less than 3 pounds of nitrogen, 1 of phosphoric acid and 4 of potash, which would cost less than 60 cents to return to the land.

It is thus shown that crops like wheat and hay possess a relatively low commercial value, and yet carry away, when sold, a very considerable amount of the fertilizing constituents, while vegetables and fruits, as illustrated by the asparagus and the apples, have a high commercial or

market value, and carry away but minimum amounts of the fertilizing constituents. This distinctive character of crops, while not an absolute guide as to the profits that may be obtained from the use of fertilizers, — since the cost of production varies widely for each class, — is instructive in showing that those of a low commercial value are more exhaustive than the other class, or those of a high market value, and is certainly suggestive, pointing out the necessity for judgment in the application of fertilizers that shall be made in the case of crops of the different groups.

The kind of farming, whether "extensive or intensive."

Another very important consideration, and one which exercises an influence, is whether the farming engaged in is "extensive" in its character, or "intensive"; whether the purpose or idea is simply to supplement the stores of plant-food in the soil, or whether the object is to insure an abundance of all forms of constituents under all reasonable conditions, in order that a maximum production may be secured.

PLANTS VARY IN THEIR POWER OF ACQUIRING FOOD

In the next place, the character or feeding capacity of the plant and its season of growth should be considered, that systematic methods may be adopted, and thus not only that waste of fertilizing materials may be avoided, but that the applications may be made at such times and in such amounts as will, other things being equal, promote the greatest increase per unit of applied food.

While each plant possesses individual characteristics which distinguish it from all others, for our purpose they may again be classified into general groups which possess

somewhat similar characteristics, particularly as to their method and time of growth and their capacity for acquiring food from soil sources.

Characteristics of the cereal group.

The cereals possess distinct characteristics of growth. The roots branch just below the surface, and each shoot produces feeding roots, which distribute themeslves in every direction, and thus absorb food from the lower layers of the soil as the plant grows older. Because of their wide root system, and because of the character of their feeding rootlets, they are able readily to acquire food from the insoluble phosphates and potash compounds of the soil, though they are unable to feed to any extent upon the insoluble nitrogen. Furthermore, inasmuch as the most rapid development of many of these crops takes place early in the summer, before the conditions are favorable for the rapid changing of organic nitrogen into nitrates, they are, with the exception of Indian corn (maize), specifically benefited by early applications of nitrogen in the form of nitrate. The corn, on the other hand, which makes its most rapid growth after the other cereals are harvested, — in July or August, — when the conditions are particularly favorable for the development of nitrates, do not usually require as large proportions of nitrogen as of the mineral constituents, particularly the phosphates. That is, wheat, rye, oats and barley are specifically benefited by the early application of quickly available nitrogen.

Characteristics of grasses and clovers.

Forage crops, including both the grasses and clovers, constitute another group, in so far as their use is concerned,

though possessing marked distinguishing characteristics. Of the grasses, nearly all species are perennial, though their length of life depends upon the method of cropping and upon the character of the soil. They send their fibrous roots into the surface soil in the same manner as the cereals, though they differ from them in forming a set of buds which become active in the late summer and develop new roots and shoots. They resemble the cereals in their power of acquiring mineral food, and are even more benefited by the application of nitrogen, since the chief object in their use is to obtain the nitrogenous substances contained in leaf and stem in the form of pasture, forage or hay, rather than the matured grain. Hence, nitrogen, which promotes this form of growth, is an important constituent, and under any conditions there should be a liberal supply provided.

The clovers, on the other hand, are not perennial, with the partial exception of "white" or "Dutch" clover, and with this exception they all possess a taproot, which penetrates downward, and as it descends, throws out fibrous roots into the various layers of soil. They are capable of readily acquiring their mineral food, both because of their large root systems and because of the character of the roots. They, however, differ in one very important particular from the cereals and grasses, in that under proper conditions, as already pointed out (p. 129), they are capable of acquiring their nitrogen from the air. Thus with liberal dressing of only phosphoric acid and potash, maximum crops may be secured. They are "nitrogen gatherers," and the tendency of their growth is to improve the soil for the nitrogen consumers, or for those that obtain their nitrogen only from soil sources.

Root crops.

Another class of plants, differing from those already described, includes the root crops, as beets, mangels, turnips and carrots. These plants cannot make ready use of the insoluble mineral constituents of the soil. Hence, in order to insure full crops, they must be liberally supplied with available food. Of the three classes of fertilizing constituents, the phosphates are especially useful for turnips, while the slower-growing beets and carrots require that the nitrogen shall be in quickly available forms. The proper fertilization of sugar beets, for example, is of great importance, since not only is the yield affected by fertilization, but the quality of the beet for the production of sugar.

White potatoes and sweet potatoes, the one a tuber, the other an enlarged root, constitute another class which does not possess strong foraging powers. They require their food in soluble and available forms, and with suitable soils potash is the ingredient that is especially useful in the manures applied.

Market-garden crops.

Another group of crops is distinguished as a class, not so much because of their peculiar habits of growth as because of the objects of their growth, though this latter fact has a very important bearing upon economical methods of fertilization. This class includes what are called "market-garden crops," as lettuce, beets, asparagus, celery, turnips, cucumbers, melons, sweet corn, beans, peas, radishes and various others. The particular object in raising these is to secure rapidity in growth, and thus to insure high quality, which is measured by the element of succulence. In order

PLATE IX. — Lima Beans and Potatoes.

FIG. 17. — NINETY-ACRE FIELD OF LIMA BEANS FOR CANNING, FREEHOLD, NEW JERSEY. A GOOD EXAMPLE OF A FIELD TRUCK CROP.

FIG. 19. — ONE TON OF HIGH-GRADE FERTILIZER USED UPON EARLY POTATOES IS THE COMMON PRACTICE AMONG GROWERS IN NEW JERSEY.

that this may be accomplished, they must be supplied with an abundance of available plant-food, and since nitrogen is the one element which more than any other encourages and stimulates leaf and stem growth, its use is especially beneficial to all of these crops. They must not lack for this element in any period of their growth, though, of course, a sufficiency of minerals must be supplied in order that the nitrogen may be properly utilized. Because of their high commercial value, the quantity of plant-food applied may be greatly in excess of that for any other of the groups, and profits, as a rule, are measured by this excess rather than by the proportion of the elements.

Fruit crops.

Another distinct class of crops, though differing materially in their individual characteristics, as well as in their time and period of growth, are the fruits. These differ from most other crops, in that a longer season of preparation is required, in which the growth may be so directed as to prepare the plant or tree for the proper development of a different kind of product, namely, fruit, as distinct from grain or seed in the cereals, or succulence in the vegetable crops. The fruit differs in its characteristics from the ordinary farm crops, in that its growth and development require a little different treatment, since it is necessary that there shall be a constant transfer of food from the tree to the fruit throughout the entire growing season. The growth of each succeeding year of tree and fruit is dependent, not altogether upon the food acquired during the year, but as well upon that acquired in the previous year, and which has been stored up in bud and branches. A knowledge of the habits of growth, the period of growth and the object of the growth of this class is,

therefore, useful as a guide to the economical supply of the essential elements of growth. These crops must be provided with food that will encourage a slow and continuous rather than a quick growth and development.

SYSTEMS OF FERTILIZING SUGGESTED

A careful review of the foregoing facts furnishes abundant evidence of the impracticability of attempts to give information concerning the use of fertilizers that will apply equally well under all of the conditions of farming that may occur. Nevertheless, there have been a number of methods or systems of fertilization suggested, each of which possesses one or more points of advantage.

A system based upon the specific influence of a single element.

The one which has perhaps received the most attention, doubtless largely because one of the first presented, and in a very attractive manner, is the system advocated by the celebrated French scientist, George Ville. This system, while not to be depended upon absolutely, suggests lines of practice which, under proper restrictions may be of very great service. In brief, this method assumes that plants may be, so far as their fertilization is concerned, divided into three distinct groups. One group is specifically benefited by nitrogenous fertilization, the second by phosphatic, and the third by potassic. That is, in each class or group, one element more than any other rules or dominates the growth of that group, and hence each particular element should be applied in excess to the class of plants for which it is a dominant. In this system it is asserted that nitrogen is the dominant ingredient for wheat, rye, oats, barley, meadow grass and beet crops. Phos-

phoric acid is the dominant fertilizer ingredient for turnips, Swedes, Indian corn (maize), sorghum and sugar cane; and potash is the dominant or ruling element for peas, beans, clover, vetches, flax and potatoes. It must not be understood that this system advocates only single elements, for the others are quite as important up to a certain point, beyond which they do not exercise a controlling influence in the manures for the crops of the three classes. This special or dominating element is used in greater proportion than the others, and if soils are in a high state of cultivation, or have been manured with natural products, as stable manure, they may be used singly to force a maximum growth of the crop. Thus, a specific fertilization is arranged for the various rotations, the crop receiving that which is the most useful. There is no doubt that there is a good scientific basis for this system, and that it will work well, particularly where there is a reasonable abundance of all of the plant-food constituents, and where the mechanical and physical qualities of soil are good, though its best use is in "intensive" systems of practice. It cannot be depended upon to give good results where the land is naturally poor, or run down, and where the physical character also needs improvement.

A system based upon the necessity of an abundant supply of the minerals. (Wagner System.)

Another system which has been urged, notably by German scientists, is based upon the fact that the mineral constituents, phosphoric acid and potash, form fixed compounds in the soil, and are, therefore, not likely to be leached out, provided the land is continuously cropped. They remain in the soil until used by growing plants, while the nitrogen, on the other hand, since it forms no fixed

compounds and is perfectly soluble when in a form useful to plants, is liable to loss from leaching. Furthermore, the mineral elements are relatively cheap, while the nitrogen is relatively expensive, and thus the economical use of this expensive element, nitrogen, is dependent to a large degree upon the abundance of the mineral elements in the soil. It is, therefore, advocated that for all crops and for all soils that are in a good state of cultivation, a reasonable excess of phosphoric acid and potash shall be applied, sufficient to more than satisfy the maximum needs of any crop, and that the nitrogen be applied in active forms, as nitrate or ammonia, and in such quantities and at such times as will insure the minimum loss of the element and the maximum development of the plant. The supply of the mineral elements may be drawn from the cheaper materials, as ground bone, tankage, ground phosphates and iron phosphates, as their tendency is to improve in character; potash may come from the crude salts. Nitrogen should be applied chiefly as nitrate of soda, because in this form it is immediately useful, and thus may be applied in fractional amounts, and at such times as to best meet the needs of the plant at its different stages of growth, with a reasonable certainty of a maximum use by the plants. Thus no unknown conditions of availability are involved, and when the nitrogen is so applied, the danger of loss by leaching, which would exist if it were all applied at one time, is obviated.

This method also possesses many advantages, particularly where the "intensive" system is practiced, though it is also useful in quickly building up wornout soils, or those naturally poor, because in any case these must be provided with liberal supplies of the minerals, and when these only are applied, the immediate outlay is far less

than if the expensive element, nitrogen, were included; and a greater economy in the use of nitrogen is accomplished if it is added in small amounts when required. Besides, in the improvement of soils, the liberal application of the minerals is conducive to an abundant growth of the legumes, which are able to acquire their nitrogen from the air, thus reducing to some extent the outlay for this expensive element. This system is strongly recommended where cheap phosphatic and potassic materials are readily accessible, as is the case in those countries where it is successfully used.

A system based on the needs of the plants for the different elements as shown by chemical analysis.

Another system of fertilization is based upon the theory that the different plants should be provided with the essential elements in the proportions in which they exist in the plants, as shown by chemical analysis. Different formulas are, therefore, recommended for each crop, the constituents of which are so proportioned as to meet its full needs. This method, if care is taken to supply an abundance of all the necessary constituents, may result in a complete though perhaps not an economical feeding of the plant, since it assumes that a plant which contains a larger amount of one constituent than of another requires more of that constituent in the fertilizer than of the others. It does not take into consideration the fact that the plant which contains a larger amount of one element than another may possess a greater power of acquiring it than one which contains a smaller amount.

Neither does this system take into consideration, as already pointed out (p. 199), that the period or time of growth of the plant also exercises a considerable influence in indicating the capability of the plant to acquire its necessary

food from the stores of the soil, as may be illustrated by wheat and Indian corn, which both contain a relatively high content of nitrogen. Under good conditions of soil, wheat is specifically benefited by heavy dressings of quickly available nitrogen. Corn is not, and one reason is, that they possess different powers of acquiring food, due, to a considerable extent, to the difference in their time of growth, as well as to the period or time of their most rapid growth.

This method may, however, be applied with very great advantage in greenhouse work, or in growing market-garden crops, where the amounts in the soil are not regarded as of importance, and excessive amounts of all are added. The system has been elaborated to a great degree of nicety for the growing of greenhouse crops, flowers and foliage plants, so much so that now artificial manure cartridges are prepared, which contain the amounts and kinds of food shown by the analysis of the different plants to be needed for their growth and full development. "The manure has the form of a fine powder, enclosed within a metallic wrapper, and firmly compressed into the shape of a cartouche or capsule, cylindrical in form, about three-fourths inch across and one-half inch in depth. It is simply thrust into the soil of the pot to a depth of one-half or one inch, and allowed to remain. After a time it is found that the fertilizer gradually disappears, and at length nothing is left but the little pill-box-like wrapper, which originally contained the mixed fertilizing powder." [1]

A system in which the fertilizer is applied to the "money crop" in the rotation.

Another system is also recommended, which is well adapted for "extensive" farming, where the majority of

[1] "The Gardener's Chronicle," London, England.

crops which are grown in rotation possess a high fertility value and a low commercial value, and where one crop is regarded as the chief "money-maker." The system demands that to this crop shall be applied such an abundance of plant-food as to insure a continuous feeding, and a consequent maximum production, even though adverse conditions intervene. Thus by a liberal supply of food, a money crop is secured which is as large as climate and seasonal conditions will permit, though which does not require all of the food applied. Hence the residue may be depended upon to fully nourish the remaining crops in the rotation, or at least the immediately succeeding ones, thus saving direct outlay for them. This system may be illustrated as follows:

On soils in good physical condition, and naturally well adapted for growing potatoes, this crop is selected as the "money-maker" in the rotation, which consists of corn, potatoes, wheat, clover and hay. The potato crop is fertilized so liberally, say with 1500 pounds to the acre, of a fertilizer containing —

Nitrogen	4%
Phosphoric acid	8%
Potash	10%

as to insure its maximum growth under average conditions. The removal of a large crop would still leave a large residue of plant-food, which would provide the following wheat crop with at least all of the mineral elements necessary to produce a maximum crop. If the wheat does not show vigorous growth in the spring, it is lightly top-dressed with nitrate of soda, which not only feeds it directly with nitrogen, but strengthens and invigorates the plant, enabling it to secure the minerals needed. The removal of a

large crop still leaves an unused residue, upon which the clover crop following is also able to make a maximum growth, and thus three crops are fertilized with the one application. The hay is either fertilized with both the minerals and nitrogen, or lightly top-dressed with nitrogen early in the spring. The yard manure, accumulated from the residue of straw, hay and corn, is applied to the corn, which, being a gross feeder, is able to obtain from this an abundance. Thus, by the heavy application of fertilizer upon the "money crop," all the crops in the rotation are benefited.

This method possesses many valuable features, and is, perhaps, quite as well adapted as any other for this system of farm practice.

An irrational system.

The most expensive and irrational system of all, and one more commonly practiced than any other in general farming, may be termed the "hit or miss" system; if a "hit" is made, there is a profit, if a "miss," the loss is trifling. In this system, no special thought is given to the character of the crop or its needs. If the farmer can afford it, he purchases a fertilizer, without regard to its composition, and applies it in very small amounts. If it happens to contain that element which is particularly needed for the plant to which it is applied, a profit is secured. In too many cases, however, the constituents added are already in abundance in the soil, or so little of the fertilizer is used as to preclude any profit.

SUMMARY

With the exception of this last system, there are good features in all of these suggested methods of use, and it

rests with the farmer to select the best points from each, or rather to use the suggestions in each which are in his judgment more applicable to his conditions. They are all based upon underlying principles, and pre-suppose a knowledge of them on the part of the farmer. They are, at best, but guides or sign-posts pointing toward better methods in the use of fertilizers, rather than absolute rules to be followed blindly.

It may be pointed out that these systems do not take into consideration the character of the soil. Vast differences exist between soils, not only in their natural content of plant-food but also in their physical and mechanical character, which is so important in the retention and liberation of plant-food. Nor do these systems give appreciation to rational farm practices such as green-manuring and liming which have such a material effect upon the soil stores of plant-food. In view of these facts the good points of the various systems should not only be utilized but they should also be fortified by experimentation. A more complete discussion of simple experiments for this purpose may be found in the following chapter.

The suggestions here and in subsequent chapters, in reference to the use of fertilizers, are formulated from the best information obtainable by the writer, and mainly from two sources: First, the results of experimental inquiry, and, second, the results of the observation and experience of practical men. In no case can absolute rules be laid down. Farmers may safely rely on the well-established principles, but each must remember that the use of the principles must be modified according to his own conditions.

CHAPTER XII

FERTILIZERS FOR CEREALS AND GRASSES

It has already been pointed out (p. 198) that these crops are classed as possessing a relatively low commercial value and a relatively high fertility value, and that, from a practical standpoint, in any fertilization of them a possible profitable return should be borne in mind. This is, of course, necessary in all cases, but is particularly necessary where an increased yield, as great as can be expected from an application of proper fertilizing materials, cannot possibly result in an extraordinary profit, a result quite possible with certain crops of the opposite class. The possible increase in yield, also, is dependent on the conditions of soil and season, and if these latter are such as to forbid a maximum increased yield, the immediate profits from the application are reduced considerably.

It has been shown, also, by careful experiments that, on the average, at least one-third of the nitrogen applied to these crops, although contained in the best forms, is not secured in the crop, even under the most favorable conditions; that is, in any case certain amounts are lost through drainage, the growth of weeds and denitrification; and, further, that the minerals must exist in the soil, or must be supplied in sufficient excess, otherwise the utilization of the nitrogen by the plant is still further reduced. The expense of fertilizer to the unit of increase in these crops

is, therefore, relatively greater, even under the best conditions of its use. A bushel of wheat, with its accompanying straw, will contain, for example:

Nitrogen	1¾ lbs.
Phosphoric acid	¾ lb.
Potash	1¼ lbs.

It will be observed that the amounts of fertilizer ingredients contained in the crop are such that if the seasonal

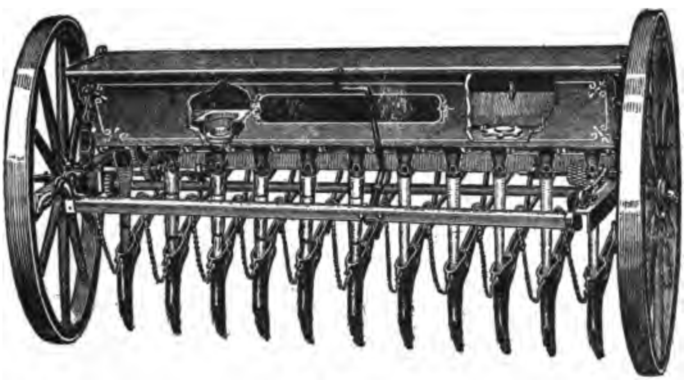


FIG. 14. — GRAIN DRILL WITH FERTILIZER SOWER.

The grain drill with fertilizer sower has justly come into very general use. It sows the seed and evenly distributes fertilizer, at the same time covering both with sufficient soil.

conditions are perfect, so that the maximum of the amounts applied are recovered in the crop, the cost of fertilizers to a bushel of increase is still relatively high, thus showing that great care must be exercised in order that a direct and immediate profit may be secured. Nevertheless, since the cost of preparing the land and of harvesting the crop is but slightly greater for a large crop than for a small one, the larger returns for the labor very

frequently pay well for the application of the material, even though the margin of money profit is small. In crops of this sort therefore, and especially when grown on the "extensive" plan, an important point to be determined is whether the land is deficient in all of the constituents for grain and hay growing, or whether only one or two are lacking, in order that in the applications made, only those constituents are supplied that are necessary, and adding to an excess already present is thus avoided, with a consequent saving in the cost of the fertilizer.

EXPERIMENTS TO DETERMINE THE LACKING ELEMENT

The lacking element cannot be fully determined, except by direct experiments by the farmer himself. That is, no general principle can be depended on as an absolute guide. He should learn whether his soil is deficient in any of the elements, and, if so, which ones should be applied to the different crops in his rotation. A careful study along this line, too, will show whether it is fertilization that is required to meet seeming deficiencies, for it frequently happens that the needs of the soil are not so much for added plant-food as for better management of the soil in other respects, in order that natural supplies may be made more available.

It may seem, at first glance, that experimenting should be left to the experiment stations, and that farmers should be advised by them of the needs of their soils in respect to plant-food. This is partly true, but the proper function of experiment stations is to establish principles, the application of which must be left, in large part at least, to the intelligence of those who are to utilize them.

The farmer must study his own conditions. Scientific inquiry has established the facts that soils differ in their content of the different plant-food elements, and that those of practically the same chemical composition differ in respect to their physical qualities, which conditions exercise an important influence upon the availability of the constituents.

This experimenting may also seem to be a troublesome operation, yet, if thoughtfully managed, it will mean but little extra labor, and the resulting gain may be far in excess of the cost of the work. For example, if it is shown that fertilization under certain conditions is not needed, and therefore not profitable, it saves possible outlay at once; if it shows that the application of certain of the constituents is a profitable practice, it enables the adoption of a systematic scheme of fertilization.

A scheme for plot experiments.

The following simple scheme of plot experimenting has been suggested, and it admits of determining many of the points involved. This scheme includes ten plots, in which three are to be cropped without manure, as check plots, in order to show the productive capacity of the unmanured land. The plots may vary in size, though it is desirable that they should contain at least one-twentieth of an acre, and that they should be long and narrow (one rod wide and eight rods long is a size), in order to include as many inequalities of the soil as possible; though in any case land as uniform as possible in physical and chemical qualities, and fairly representative, should be selected. The following plan permits of a study of the effect of the application of individual constituents, and of their various combinations. If desired, in order to sim-

plify the work in the beginning, only the first four plots need be taken. This will reduce the labor, and, at the same time, permit a study of the soil's deficiencies in respect to single elements of plant-food, and the relative needs of the different crops for the various constituents.

The rate of application to the acre is greater than would naturally obtain in practice, in order to facilitate the distribution of the fertilizer, to furnish a sufficient abundance of the constituent, and to provide against unfavorable conditions.

Preferably, the application should be made broadcast, and before planting, though for cultivable crops it may be applied later and harrowed into the soil.

It will be observed that the amounts of fertilizer are one pound to the square rod, or multiple thereof. Thus, in order to insure an equal distribution over the entire area, it may be roughly divided into plots of a square rod, and the required material for each rod applied separately. Careful weights should be made of the yields of the different plots, as a basis of comparison. The same fertilizers should be used on the different crops of the rotations, and as interest is increased in the work, different forms and amounts of the various constituents may be introduced.

Results that may be attained.

If it is found that for a certain crop only one of the applied constituents profitably increases the yield, then that should be used until the need of the others is apparent. If two are needed to accomplish the results, use two, and so on; though in the long run, or as the practice approaches the "intensive" system, all will doubtless be required. In "extensive" farming this is a very

PLAN OF EXPERIMENT — SIZE OF PLOTS, $\frac{1}{20}$ OF AN ACRE

132′

16½′

Plot I.	Check — No fertilizer.	
Plot II.	Nitrate of soda.	8 pounds.
Plot III.	Acid phosphate.	16 pounds.
Plot IV.	Muriate of potash.	8 pounds.
Plot V.	Check — No fertilizer.	
Plot VI.	Nitrate of soda. Acid phosphate.	8 pounds. 16 pounds.
Plot VII.	Nitrate of soda. Muriate of potash.	8 pounds. 8 pounds.
Plot VIII.	Acid phosphate. Muriate of potash.	16 pounds. 8 pounds.
Plot IX.	Nitrate of soda. Acid phosphate. Muriate of potash.	8 pounds. 16 pounds. 8 pounds.
Plot X.	Check — No fertilizer.	

desirable line of experimentation, and can be carried out by individual farmers. It is useful not only in showing the deficiencies of the soil for the various crops, but is educative in its character, as it familiarizes the farmer with the materials that are used in making fertilizers, and encourages exact methods of work. Since, as already stated, the need very frequently is not so much for added fertility as it is for better preparation and cultivation of the soil, or for amendments such as lime, it would be a desirable practice to include in the number of plots here indicated one or two in which the cultivation of the soil was made more perfect, in order to determine whether the need is for more fertility elements or whether it is for better tillage, the effect of which is to render more of the soil constituents available to the plant. One or two to which lime is added may be advisable, in order to determine whether this substance is needed either to correct acidity or to make available otherwise unusable compounds. This method, while particularly desirable where "extensive" methods of practice prevail, is of less importance where the aim is to grow maximum crops, in which case both the crop and its rotation are to be considered, and the needs of the plant rather than the deficiencies of the soil require first attention.

The results of experiments which have been conducted with great care in a number of states show that where "extensive" methods are practiced certain elements need not be added in the fertilizers; that is, that the soil contains such an abundance of them that the plant is able to obtain a full supply, at least, for a long time. For example, it has been shown that on the chief sugar-producing soils of Louisiana and Mississippi, and the cotton soils of Georgia and Texas, the addition of potash has been

of less importance in the past than the other elements, and it frequently does not need to be included in the fertilizer, while phosphoric acid is always needed.

The results of field experiments on this plan in New Jersey, on reasonably good, loamy soils, indicate that phosphoric acid and potash are of much more importance in fertilizers for corn than nitrogen, whereas upon sandy soils, nitrogen and potash are of relatively more importance than phosphoric acid; that is, even where "extensive" practice is used there are conditions where one or more of the elements are not required in order to secure maximum crops, which eliminates the necessity for an immediate outlay for those constituents that are not lacking. Where experiments of this sort have not been carried out and the specific needs determined, it becomes necessary to assume that all of the constituents are required, and to apply the amounts and proportions of those which the general considerations of the soil, season, climate and crop would seem to demand.

As already pointed out, the methods of fertilization here suggested, though in many instances apparently positive, are not to be interpreted as absolute rules, but rather used as guides, based upon the best information that it has been possible to obtain, both as a result of scientific inquiry and of practical experience.

THE IMPORTANCE OF SYSTEM IN THE USE OF FERTILIZERS

The following rotation is assumed, in order to show the necessity of a definite system of work, which is quite as important in this branch of farming as in many others in which system is apparently more essential, — though in fact it is quite as necessary to observe a definite system

in the feeding of plants as in the feeding of animals with the plants.

ILLUSTRATION OF A ROTATION

First year	maize (corn)
Second year	oats
Third year	wheat
Fourth year	clover and timothy
Fifth year	timothy hay

Indian corn exhaustive of the fertility elements.

Since in rotations of this sort a fair number of live stock is usually kept, a considerable amount of manure is made, which should be carefully cared for and used, as it contributes materially to the success of the plan. The manure may be used in part on land for corn, and should be spread broadcast, practically as fast as made during the fall, winter and early spring. Corn, because it is a gross feeder, and because it makes most of its growth during the summer season, when activities in the soil are most rapid, is able to appropriate from the coarse manures a larger proportion of the constituents than would be possible for crops which make their greatest growth earlier or later in the season. In the summer, too, the conditions are most favorable for nitrification, and soils which possess a fair content of vegetable matter are usually able to furnish the nitrogen needed in addition to that supplied in the organic manures, particularly in the middle and southern states. The considerable amounts of potash required for the growth of stalks, and the phosphoric acid for the formation of grain, demand that a liberal supply of these constituents be provided, and the fertilizer for the corn should, therefore, contain an abundance of available phosphoric acid and of potash.

PLATE X. — Fertilizers and Tomatoes.

Fig. 20. — Early Tomatoes Grown in Light, Sandy Soil, Thorofare, New Jersey.

Fig. 21. — Growth of Clover along Tomato Rows Heavily Fertilized the Preceding Year, Moorestown, New Jersey.

A crop of 50 bushels of shelled corn to the acre, with the accompanying stalks, will remove, on the average, 80 pounds of nitrogen, 29 of phosphoric acid and 55 of potash. It is an exhaustive crop. A fertilizer, therefore, that would furnish 30 pounds of phosphoric acid and 40 of potash would be regarded as a fair dressing for land of medium quality, provided a liberal application of manure had been made to the land. A part of the phosphoric acid, at least, should be in a soluble form, in order to supply the early needs of the crop. The remainder may consist of ground bone or tankage, if the phosphoric acid in these can be obtained more cheaply, since they will decay rapidly enough to supply the demands for the later growth. The potash may be either muriate of potash or kainit, though the former is preferable if it is applied in the drill, which is, if used in these amounts, a perfectly safe practice so far as injury to the plant is concerned; though fertilizers containing large amounts of potash salts are preferably applied broadcast on raw ground of a clayey nature, and well worked into the soil, thus insuring a good distribution. The cost of an application of this sort will be relatively small, and the minerals added will be more than sufficient to provide for a considerable increase in crop.

This recommendation is general and applies more particularly to soils of high natural fertility. The soil, cropping system and method of manuring have much to do with the fertilization of corn. If the land is light and sandy, nitrogen should be added, even though it has received a good dressing of yard manure, as these lands are usually deficient in this element, and organic forms are usually quite as useful as the soluble nitrate or ammonia, since the seasonal conditions during the period of growth

are favorable for the rapid change of the nitrogen in materials of good quality, like blood, concentrated tankage, or cotton-seed meal, into nitrates. The amounts of nitrogen needed would, under ordinary conditions, be supplied by 100 pounds of high-grade blood, or 200 pounds of cotton-seed meal, or by deriving equal parts of the nitrogen from nitrate of soda and tankage. Other changes are also required according to the cropping system. In the rotation mentioned above corn follows a timothy, which, if properly top-dressed each spring, supplies a large amount of organic matter, and fertilizer may be used in smaller quantity, and a smaller amount, especially of the more slowly available nitrogen, may be included in the mixture. The same is true if a rank leguminous cover-crop is plowed under or if the ground is heavily manured. If corn is grown for grain one year and silage the next, a more abundant application should be made the second year; 20 pounds of nitrogen, 30 of phosphoric acid and 40 of potash is none too liberal.

Whatever the practice of cropping, in this matter of fertilizing, it must be remembered that weeds appropriate plant-food quite as readily as the corn, wherefore in order to obtain the best results from the fertilizers added, clean cultivation should be practiced.

Oats.

For the oat crop that follows corn, and which makes its best growth early in the season, before nitrification is rapid, quickly available forms of nitrogen are very desirable; and inasmuch as the oats require an abundance of phosphates, a fertilization with phosphoric acid is also essential. Hence, fertilizers consisting of mixtures of nitrate of soda and superphosphates have

proved of great value for this crop. An application of 8 pounds of nitrogen and 18 of phosphoric acid, or 200 pounds to the acre of a mixture of 50 pounds of nitrate of soda and 150 of acid phosphate, has proved quite as profitable on medium soils as heavier applications, mainly because the oat crop is a less certain one than corn; besides, it frequently suffers severe losses in harvesting, which increase the risk from an expensive fertilization. The application of potash is not so necessary if added in the fertilizer for corn, as suggested, except on light, sandy soils.

It is not a profitable practice to use much manure in oats land, if any, because it is liable to cause a stalky growth and subsequent lodging and loss in harvest, and furthermore, it may be utilized so much more profitably for corn or some other crop which makes more of its growth in mid-summer when the soil activities are at their greatest.

Barley.

The fertilizer requirements of barley are similar in many ways to those of oats, although greater care should be used in the application of nitrogen, especially should the object of their growth be for malting. For this purpose, a plump, heavy, well-ripened grain, rich in nitrogen, is required. Too rank a growth of straw, caused by an abundance of nitrogen, is often accompanied by immaturity of grain; besides, in moist seasons it is also likely to assist in the promotion of rust.

A fertilizer, therefore, which will help to avoid these dangers, and at the same time supply the needs of the plant, may be made up of 50 pounds of nitrate of soda, 150 of acid phosphate and 25 of muriate of potash to the acre. This mixture used at the time of seeding will supply

the needed minerals and sufficient nitrogen to give the plants a good start. From three weeks to a month after seeding, an application of 50 to 75 pounds of nitrate of soda to the acre will help to insure a proper development and maturity, and provide for the largest yield of grain without injuring the quality for malting purposes.

Wheat. (See Fig. 15, Plate VIII.)

The fertilizing of wheat will depend largely upon the treatment of preceding crops. For wheat following the oats crop, the remainder of the manure may be applied before plowing, well harrowed into the surface soil, and a fertilizer rich in available phosphoric acid, and containing only a sufficient amount of nitrogen in available forms to insure a good fall growth applied. When the land has been well fertilized for previous crops, a dissolved animal bone superphosphate is an excellent fertilizer, because it contains the elements, phosphoric acid and nitrogen, in good forms and proportions. Dissolved bone, however, is rather scarce and an expensive source of plant-food, and a mixture composed of 25 pounds of nitrate of soda, 75 of ground bone, 200 of acid phosphate and 25 of muriate of potash will give quite as satisfactory results. If more nitrogen is needed than is provided by 200 to 300 pounds of this fertilizer in order to mature the crop, which is frequently the case, particularly if the winter has been severe, or if the land is light, it may be applied in the spring, and preferably in the form of a nitrate, which distributes readily, and is immediately available, advantages not possessed by other forms. At this period of its growth, the crops need to make a rapid appropriation of nitrogenous food, though the conditions are not yet favorable for the change of nitrogenous organic compounds in the soil

into the available nitrate. The top-dressings should be made as soon as the crop has been well started, and should range from 75 to 150 pounds to the acre, according to the character of the soil and previous fertilization. The better the natural character of the soil and its treatment, the larger the dressing that may be applied with possible profit, though in no case should it exceed the larger amount. In many cases it is advisable to make the spring application of nitrate of soda at intervals of two weeks or more.

Rye.

Rye is often used in this rotation, especially when a poor field comes around, because it is often considered a scavenger. In spite of this it is a crop which responds to good cultivation and fertilization. The use of a fertilizer, rich in phosphoric acid and available nitrogen, is especially recommended. An application of 50 pounds of nitrate of soda, 200 of acid phosphate and 25 of muriate of potash should supply ample food to insure a good fall growth.

In order to provide an abundance of available nitrogen for a maximum crop of both straw and grain, the rye should be top-dressed in spring with at least 100 pounds of nitrate of soda to the acre, broadcast, just as soon as the plants start. At this season of the year, the requirements of the plant are the greatest, and the supply of available nitrogen in the soil very meager; hence such an application fully meets the special needs of the plants for nitrogen.

Clover.

There are a number of types of clover which are sown in wheat when the ground is honeycombed in spring and

follow it as a crop. Among these, red, mammoth red, alsike and white clover should be mentioned. "As clover is a legume, it is not usually benefited by the addition of nitrogenous manures, except in the early stages of growth. On soils not well supplied with vegetable matter, manures are very beneficial, primarily in correcting the deficiencies, and in providing a more favorable medium for the development of specific bacteria. The size of the crop will be measured to some extent, also, by the abundance of mineral elements, thus enabling the plant to employ to full advantage its capability of gathering nitrogen. In many cases, particularly on soils that are likely to heave, a mulch of manure is very beneficial as a protection." An application of 100 pounds of acid phosphate and 50 of muriate of potash or one which will furnish 14 pounds of phosphoric acid and 25 pounds of potash to the acre marks the minimum dressing, and it may be applied with advantage immediately after the wheat is harvested.

Timothy. (See Fig. 16, Plate VIII.)

The timothy, the next crop in the rotation, is a member of the grass family, and is especially benefited by nitrogenous fertilization, and top-dressings in the spring with nitrate of soda have proved of great value on soils well supplied with minerals, though experienced farmers have learned that better results are obtained if the minerals are applied with the nitrate, thus insuring a better growth and development of plant. A mixture made up of 100 pounds of nitrate of soda, 150 pounds of acid phosphate and 50 pounds of muriate of potash, at the rate of 300 pounds to the acre, is now used by many successful hay-growers. In an ordinary season, such an application may

be relied upon nearly to double the timothy crop. Under some conditions a slight change of the mixture is advisable. Upon heavy soils or limestone soils, the muriate of potash may be reduced to one-half or even omitted entirely. The nitrate of soda may be increased in mixtures for the same type of soil to 150 pounds, but care should be exercised in this matter because too large a proportion of nitrate of soda is liable to cause too rapid a growth and subsequent lodging and "firing." It is often stated that nitrate of soda causes a light, leafy hay, but this is only true when the mixture is not properly balanced. It is not profitable to top-dress timothy sods unless there is a sufficient number of plants on the ground to make efficient use of the plant-food which is immediately available and subject to loss if not used. The proportionate increase in crop would be the same, but the increase in yield would not be large enough to show a profit over cost of application. In every instance the application should be made as soon as the crop has well started in the spring.

The system of fertilization here outlined is not to be advocated except under circumstances where it is not possible or practicable to supply such an abundance of plant-food as will guarantee a maximum production, as in "intensive" practice, in which the yield is measured by climatic and seasonal rather than soil conditions, but rather such additions as will return a profit and at the same time tend toward the improvement of soil. This system is economical in the use of nitrogen, the most expensive element. It provides a sufficient amount of available plant-food to insure a reasonable increase in crop, and it is well adapted to lead the farmer by easy steps from the "extensive" to the "intensive" system of farming.

A gain of fertility by the rotation system.

Assuming that the increased yield of corn is 20 bushels, with accompanying stalks, of wheat 10 bushels per acre, of oats 15 bushels, of clover ½ ton and of timothy ½ ton, the amounts applied will be practically sufficient to furnish all of the potash contained in this increase, and more than sufficient to meet the demands for phosphoric acid. That is, by this system there has been applied in the materials 30 pounds of nitrogen, 64 of phosphoric acid and 80 of potash. While, if this increased crop was secured, the following amounts would be required: 71 pounds of nitrogen, 31 of phosphoric acid and 79 of potash. The considerable amounts of plant-food contained in the yard manure, and the gain from the roots and stubble of the clover, serve to supply the balance of nitrogen required, and to provide a store of unused residue for future crops.

The method, if adopted, would be more rational, and likely to result in more satisfactory returns than the one now generally practiced, namely, to purchase without particular regard to the character of the materials furnishing the constituents, or their proportions, and to apply, on the average, even less per acre than is here recommended. Assuming that 200 pounds to the acre of the average corn fertilizer, showing a composition of 2.5 per cent nitrogen, 8 of phosphoric acid and 5 of potash, were applied only to the crops corn, oats and wheat, omitting both clover and timothy, there would have been added 15 pounds of nitrogen, 48 of phosphoric acid and 30 of potash, amounts of each too small to provide for a large increase in crop, provided all were needed.

The necessity of adding more plant-food than is required by a definite increase in crop.

It may be asked, why add more of the constituents than is necessary to provide for a definite increase in crop? Assuming that the average yield of the land is twenty bushels of wheat to the acre, and the aim is to secure thirty bushels, why not add the constituents in the amounts and proportions necessary to provide for this extra increased yield, rather than any excess of these amounts? The answer is, that in order that such a result may be accomplished, the conditions would need to be absolutely perfect, so that the plant would have at its command the amount of food needed each day. If a period in the growth of the plant should be so wet or so dry as to prevent the plants from acquiring the food necessary for their continuous growth, there would be no opportunity for them to gather food faster, when the better conditions followed the unfavorable conditions, and thus to overcome the ill effects of the period of partial starvation. In other words, if there were only sufficient food to supply the plant under normal conditions of season, the plant, after a period of time during which there was no growth, could not grow faster than it did before, hence it could not catch up in its growth and make a full crop. Furthermore, the plan of applying only that needed for the increase must necessarily assume that the plant-food is in the best forms, and that the physical conditions of soil are so perfect as to cause it to absorb and retain all the food applied, and in such a manner as to permit it to be readily obtained by the plant. A further advantage is to enable the clover plant in the rotation to fully exercise its power of acquiring nitrogen from the

air. Moreover, if properly carried out, it fulfils the idea of successful agriculture; viz., the production of profitable crops, while at the same time not reducing, but increasing, the potential fertility of the soil.

The system should be modified if no farm manures are used.

In this rotation, if no manures are available, as indicated, then the amounts and kinds of fertilizers should be somewhat changed. For example, if it was necessary to supply the corn crop with a sufficient abundance of all the elements in artificial forms, then the proportions of nitrogen should be somewhat greater and the total amounts of the constituents applied to the different crops considerably increased. For corn, a mixture consisting of 20 pounds of nitrogen, 30 of phosphoric acid and 50 of potash should be applied, and if grown upon raw ground rather than upon sod, it would be desirable to still further increase the nitrogen. The oats could be fertilized, as before recommended, while the wheat should have an increased supply of both nitrogen and phosphoric acid, — double the amounts recommended when used with manure, — besides an addition of at least 10 pounds to the acre of potash. The fertilizing of the clover and timothy need not be changed. If, in a rotation of this character, barley were substituted for oats, and rye for wheat, the fertilization need not be materially changed, though the rye possesses a slightly greater power of acquiring phosphoric acid than wheat, and the nitrogenous top-dressings may be omitted, unless the crop is grown primarily for straw rather than for grain. The barley is also less able to acquire its phosphoric acid than the oats, and is especially benefited by nitrogen, though care should be exercised to regulate the amounts applied in

order to prevent lodging, which affects both the yield and quality of the grain. If in the rotation the timothy hay is omitted, then the fertilization for the corn may be reduced, as on good soils the yard manure, together with the plant-food stored in the surface in the clover sod, will furnish an abundance.

FERTILIZERS FOR A SINGLE CROP GROWN CONTINUOUSLY

When it is desirable to grow any one or all of these crops continuously (and this practice may be followed with advantage, particularly when a leguminous catch-crop is seeded with the main crop, which insures a continuous occupation of the land and also provides vegetable matter and nitrogen), the fertilization would naturally be somewhat different, and, as a rule, would require more nearly even quantities of the different constituents. For corn, a fertilizer supplying 20 pounds of nitrogen, 40 each of phosphoric acid and potash, would provide for a liberal increase in the yield from year to year. The nitrogen should preferably be in good organic forms, which would decay rapidly enough to supply the needed available nitrogen during the growing season. The phosphoric acid may be drawn partly from superphosphates and partly from organic compounds, as ground bone and tankage, provided these latter may be secured at as low a price as the superphosphate, and the potash applied in the form of a muriate or kainit. Fertilizers may be applied broadcast and well harrowed into the soil, or part may be distributed in the row at time of planting.

If a catch crop were seeded to be used as green-manure, as, for example, crimson clover, the application of nitrogen may be very materially reduced. This practice has

been followed with advantage in the middle and southern states.

For continuous wheat-growing, a fertilizer may be used at time of seeding which supplies 10 pounds of nitrogen, 40 of phosphoric acid and 20 of potash. A small part of this nitrogen would better be in the form of a nitrate, which will encourage a good top-growth in the fall, as well as a deep root system; the phosphoric acid should be soluble, in order to supply the immediate needs of the young plant, and the potash in the form of a muriate. Such an application would provide for a very considerable increase in crop, particularly if followed in the spring by a top-dressing of 100 pounds to the acre of nitrate of soda.

The top-dressing with nitrate of soda is, however, not always advisable. The chief objection to its use is that it does not encourage, but frequently seems to retard, the growth of clover, though its very great advantage is that it encourages the deeper rooting of the wheat and the more rapid growth of grasses. If continuous cropping of wheat is practiced, clover should be seeded with it, in order that the ground may be constantly occupied, and thus prevent leaching, as well as mechanical losses of fertility, and also to supply vegetable matter containing nitrogen for the succeeding crop. When a system thus outlined has been continued for a few years, the nitrogen in the fertilizer may be largely omitted.

The same considerations apply to rye as were indicated for wheat. Oats are seldom grown as a continuous crop, though if it should be desirable, a fertilizer furnishing at least 20 pounds of nitrogen, 25 of phosphoric acid and 10 of potash would be a good dressing, care being taken that a large portion of the nitrogen exists as nitrate

or as ammonia, in order to stimulate and strengthen the early growth of the plant. For the grass crop, or continuous mowing land, a fertilizer rich in nitrogen and potash should be applied. A good application in the spring may consist of 25 pounds of nitrogen, 15 of phosphoric acid and 25 of potash, and immediately after the hay is harvested a further application of at least 20 pounds of nitrogen and 30 each of phosphoric acid and potash should be applied. The nitrogen in this case may consist partly of organic forms, though the soluble nitrogen is to be preferred as top-dressings where it can be procured at such a price as to make it comparable with other forms. The nitrogen of bone, tankage and other slower-acting forms is excellent for the grasses, though these should be preferably applied and well worked into the soil previous to seeding. The early spring application should consist largely of soluble nitrogen, both to encourage a rapid appropriation of this element by the plant early in the season, as well as a deeper root-system, and consequently a greater drought-resisting power, and also to provide the elements necessary for the increased crop. The summer or later application stimulates and strengthens the roots for the coming season. If an aftermath crop is removed, or if it is pastured, a further application may be made which may consist largely of the mineral elements. This fertilization of the hay crop will also result in a richer product, for an abundant supply of nitrogen encourages a larger proportion of leaf growth, and consequently a smaller proportion of stem, containing the less valuable woody matter. Lands that are well fertilized in this way, if properly seeded in the first place, may make profitable mowing crops for a long series of years, and good crops cannot be expected unless liberal fertilization is practiced.

FERTILIZERS FOR MEADOWS

For meadows used as pastures, a more liberal application of the mineral elements is recommended, since an abundance of these encourage the growth of the clovers, which make a richer herbage than the grasses. Heavy nitrogenous fertilization is expensive, and encourages the growth of the grasses rather than the clovers. Pasturing, while less exhaustive than hay cropping, nevertheless results in the gradual depletion of fertility, and an abundant growth of rich pasturage can only be secured where there is an abundant supply of available plant-food. Mixtures made up of acid phosphate, ground bone and muriate of potash in equal proportions make very good dressings, if applied in sufficient quantity, 300 to 500 pounds to the acre annually. The ground bone is recommended because it decays slowly, and thus furnishes a continuous supply of nitrogen and of phosphoric acid. The application should preferably be made both in spring and in late summer, in order to secure a good growth, as well as to encourage the introduction of the clovers. Pastures become very acid in time and the application of lime is important. The carbonate form or ground limestone usually produces best results. Applications of 500 pounds annually or a single application of one and one-half tons every five or six years should be made. If caustic lime is used, an application of 1500 pounds every four or five years should be sufficient, though the first application might be much more liberal. In any system of continuous cropping, or in fact in any system of rotation-cropping, in which an abundance of organic matter is introduced in the way of green crops, or in decaying vegetable matter contained in roots, the

PLATE XI. — Peppers and Red Clover.

FIG. 22. — PEPPERS GROWN UNDER FIELD CONDITIONS, THOROFARE, NEW JERSEY.

FIG. 24. — EXCELLENT SECOND GROWTH OF RED CLOVER ON HEAVILY FERTILIZED POTATO LAND, FREEHOLD, NEW JERSEY.

land should occasionally receive a dressing of lime, both to supply that which the plants need, as well as to correct possible acidity of soil.

WILL THIS SYSTEM OF FERTILIZING PAY?

That fertilization will pay if carried out, as is pointed out here, and upon lands not now producing paying crops, depends, of course, very largely upon the price of the crops, the cost of the materials, and the method of farming practiced. At the prices which have prevailed in the recent past, for both crops and fertilizing materials, there is no doubt that this reasonable fertilization, together with a good system of practice in other respects, — that is, good plowing, good harrowing, good drainage and good cultivation — will result in very satisfactory returns. In fact, it has been shown by repeated experiments (see bulletins and reports of New Jersey Experiment Station) that the yields on land which is capable of producing an average crop of 15 bushels of wheat to the acre, 30 of corn and 30 of oats, may be more than doubled by an abundant supply of fertilizing materials. Such an increase results in an actual direct gain, as well as in the saving of labor per unit of product, which is accomplished when the larger crop is secured.

The main point in this whole matter of fertilization is to understand that a fertilizer is a fertilizer because of the kind and form of plant-food contained in it; and that its best action, other things being equal, is accomplished when the soil possesses good physical qualities, when the management is also good, and when systematic methods

are planned and adopted. "Hit or miss" fertilization, even for these crops, may pay, and doubtless on the average does pay as well as some other things that farmers do, but does not pay as well as it might if better methods were used.

CHAPTER XIII

FIELD TRUCK CROPS

THE truck crops differ from cereals and grasses in that they are products of high commercial value, and are less exhaustive of plant-food constituents, that is, when money value is made the unit basis. They are termed "field truck crops" because they are field crops, usually grown in rotation and form a special crop for the grower which is produced solely for market rather than for manufacture upon the farm into a farm product. In sections near large markets these crops are divided into early and late, the early crop being regarded as the more profitable; hence greater efforts are made, both in the way of fertilization and of management, to secure a large and early crop, than is the case with the late crop. For the early crop the natural supply of plant-food in the soil is not a prime consideration. In districts distant from markets, the late crop is the only one grown to any extent, and because it has the whole season for its growth, greater dependence is placed upon the natural resources of the soil. While, as already stated, these crops are not regarded as exhaustive of plant-food elements in the same sense as the cereal crops are, because it frequently happens that a bushel of potatoes, or of sweet potatoes, or of tomatoes, will bring as much as a bushel of corn, or sometimes as a bushel of wheat, yet the amount removed in the entire crop may be quite as great as in the grain crop, because of the much larger number of bushels grown an acre.

FERTILIZERS FOR POTATOES, EARLY CROP

It has been demonstrated, both by experiment and practical experience, that good crops of early potatoes require an abundance of plant-food, and that on soils of good character a heavy fertilization is usually more profitable than a medium or light application.

The plant-food removed by a fair crop — 200 bushels to the acre of tubers — will, on the average, consist of 27 pounds of nitrogen, 12 pounds of phosphoric acid and 60 of potash. Even though the increase from the application of fertilizers is less than 100 bushels to the acre, it is always advisable to add plant-food in considerable excess of these amounts: first, because the crop must be grown quickly; and second, because a large part of its growth must be made in the early season, before the natural conditions are favorable for soil activities. A study of the fertility composition of the potato shows that of the three essential constituents, the potash is contained in the greatest amount and the nitrogen next, while the amount of phosphoric acid contained in it is comparatively small. Most fertilizer formulas for potatoes are therefore prepared with the idea of furnishing a greater amount of potash than of nitrogen or phosphoric acid. Studies made by the Geneva Experiment Station shows that the formulas prepared to contain the plant-food in nearly the proportions used by the entire potato plant, excepting that the phosphoric acid is in considerable excess, were less useful than those containing very different proportions of the constituents, and which were based upon the experience of observing growers. That is, a formula of the first class, furnishing —

Nitrogen	6½%
Available phosphoric acid	5%
Potash	10%

gave less satisfactory returns for the same amount applied than one furnishing —

Nitrogen	4%
Available phosphoric acid	8%
Potash	10%

This latter formula is very generally used in sections where early potatoes are an important crop.

The time and method of application.

These are matters of considerable importance. It has been urged, particularly by German experimenters, that the potash salts, when used in such excess as seems desirable, should be applied more largely to the crop preceding, rather than directly to the potato crop. This method has not been adopted in this country to any extent, and it is believed that our climatic conditions are such as to cause a very general distribution of the salts throughout the soil, if applied, in part at least, just before planting and thoroughly distributed by cultivation. At any rate, very satisfactory returns are secured from the direct application to the crop of fertilizers of this composition. In reference to the method of application, while very good results are secured from the application of the fertilizers directly in the row, this is to some extent influenced by the character of the soil. Where the soil is somewhat heavy, and the circulation of water is not perfectly free, it is less desirable than where the soils are open and porous, and free circulation is not impeded; though where the amounts applied are considerable, it is recommended that

at least one-half of the fertilizer should be applied broadcast and worked into the soil, and the remainder placed in the row at the time of planting. Naturally, when the soils are poor, a concentration of the constituents is more desirable than when the surrounding soil possesses reasonably abundant supplies of available food.

The amount to be applied. (See Fig. 18.)

As already stated, the amount of the different constituents to be applied should be in considerable excess of

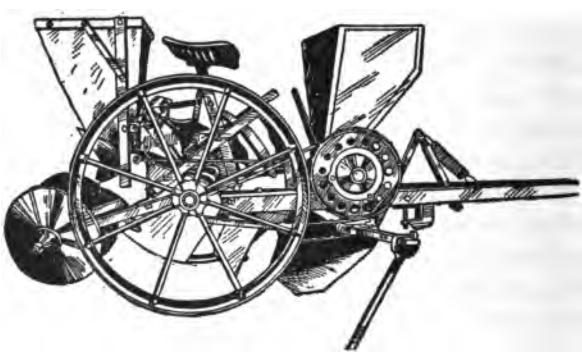


FIG. 18.—THE POTATO-PLANTER WITH FERTILIZER ATTACHMENT, WHICH DISTRIBUTES FERTILIZER EVENLY IN THE ROW.

that required by the actual increase in crop, both for the reasons already given, and because it is desirable in crops of this sort to insure a continuous and abundant feeding of the plant. Where "intensive" practice is general, the amounts applied very frequently reach a ton to the acre of the high-grade fertilizer already mentioned, though the necessity for so large an application as this has been questioned, particularly if it is expected to give rise to a profitable return in the crop to which the application is

made, and though it can be readily seen that if conditions should not be favorable, the larger amounts would be preferable. The result of investigations of this point by the Geneva Experiment Station showed that an addition of fertilizers above 1000 pounds to the acre, or 40 pounds of nitrogen, 80 of phosphoric acid and 100 of potash, was not as profitable as 1000 pounds. It must be remembered, however, that these experiments were conducted upon light soils, and on these entire dependence must be placed upon added plant-food.

In the best potato sections of New Jersey, the application of a fertilizer of this composition ranges from 1000 to 2000 pounds to the acre, while the larger part of the growers use the smaller rather than the greater quantity. (See Fig. 19, Plate IX.) Many use the larger, and are of the opinion that it is a profitable practice, because of the greater certainty of securing a good potato crop, and because the unused residue provides for large yields of the subsequent crop without further applications. The growers of potatoes in the vicinity of Norfolk, as well as farther south, also find it profitable to be generous in the use of fertilizer for this as well as for other crops of high commercial value.

The growers of Maine use the larger quantity and many are now gradually changing the composition of the fertilizer applied by increasing the nitrogen to 5 per cent and decreasing the potash to 7 per cent. It is not uncommon in Maine to make two applications during a season. This method has become known as the Aroostook County method. In some cases the fertilizer is merely divided into two parts and put on at intervals of three weeks or a month, but in other cases the first application made at the time of planting contains only organic nitrogen, whereas

the second application contains nitrogen drawn from soluble sources. The second application is made when the vines are three or four inches high and the fertilizer is dropped right on them and then the entire plant is covered with soil. When this method is practiced, it is believed that more efficient use is made of the nitrogen, and that the vines have ample opportunity for increased root development. While this method is successful in Maine, it has not proved to be superior in New Jersey and warmer climates. It is applicable to both early and late potatoes.

Form of the constituents.

In the growing of potatoes, sulfate of potash is generally recommended in preference to the muriate, owing to the supposedly deleterious effect on the quality of the tubers resulting from the large quantities of chlorids contained in the muriate, though the different forms, when properly applied, do not seem to materially influence the yield. That is, if muriate or kainit is applied previous to the planting of potatoes, the deleterious chlorids derived from the muriate may be washed from the soil. There is no doubt that the sulfate improves the appearance of the potatoes, making them more clean and uniform in size, though experiments that have been conducted do not show a material difference in the chemical composition of the tubers grown with any of the forms. The tendency on the part of the muriate seems to be to diminish the amount of dry matter, and inasmuch as the dry matter is mostly starch, the latter is thereby slightly reduced, though it has not yet been demonstrated that the good quality of the potatoes is measured by the content of starch.[1]

[1] Bulletin No. 137, N. Y. State (Geneva) Exp. Sta.; Bulletin No. 80, N. J. Exp. Sta.

In reference to the form of nitrogen, both theoretical considerations and the experience of growers confirm the belief that for the early crop a portion of the nitrogen should exist in the form of nitrate or ammonia and the remainder in quickly available organic forms, although no definite experiments have been conducted to determine this point, nor the one as to whether all of the nitrogen in the form of nitrate should be applied at the time of planting. A top-dressing after the potatoes have come up is a very desirable method of practice on light soils which have been liberally supplied with the minerals.

On good potato soils, therefore, a good fertilization would consist of 1000 pounds to the acre, as a minimum, of a mixture containing:

Nitrogen	4%
Phosphoric acid	8%
Potash	8%

The nitrogen is to be in quickly available forms; the phosphoric acid, also, is to be available, and the potash to be derived from sulfate, particularly if fine quality of crop, as indicated by appearance, is desired. If only yield is considered, the muriate is quite as serviceable.

LATE POTATOES

For late potatoes, the considerations in reference to the form of the constituents and the amount of the application, as suggested for early potatoes, do not always hold good, since in many cases the crop is able to secure a larger proportion of its plant-food from soil sources, — due, first, to the longer period of growth of the plant, and second, to the fact that the crop is usually grown upon soils naturally

richer in the plant-food elements, though the proportion of potash, as in the formulas already indicated, should be relatively large. The nitrogen may be reduced, and the form of nitrogen may be derived largely from quickly available organic sources. Good formulas for late potatoes may consist of —

Nitrogen	3%
Phosphoric acid	6%
Potash	8%

and the application may be from 800 to 1200 pounds to the acre.

Where potatoes are grown in rotations with the cereal crops mentioned in Chapter XII, the unused residue from the rather heavy application of fertilizers to the potato crop is depended upon to aid very materially the growth of these, thus reducing the outlay for fertilizer for crops of a low commercial value. This practice is advantageous, though the prime object should be to feed the crop rather than the soil — that is, apply the fertilizer with the idea of securing a profit from it in the potato crop, rather than a possible profit in subsequent crops.

SWEET POTATOES

In the growing of sweet potatoes, the quality of the product is more important than in the case of the white potato. The northern markets distinctly recognize quality in this crop, and it is measured by size, shape and results in cooking. The potato that brings the best price in the different markets is small, about the size of a white potato; in shape round, rather than oblong, and is dry and mealy when cooked. This characteristic of the crop is influenced

both by the character of the soil and of the manures and fertilizers applied. The soils best adapted are dry, sandy loams, and the most useful fertilizers are those which contain an abundance of minerals — phosphoric acid and potash — and not too large supplies of quickly available nitrogen. It is also true that the yields of sweet potatoes of this character are not as large as those that may be obtained when quality is not a prime consideration, and which are grown for the general market.

Fertilizer constituents contained in an average crop.

This crop is very similar to the white potato in regard to food required. Two hundred bushels of sweet potatoes, not including vines, contain, on the average, 30 pounds of nitrogen, 10 of phosphoric acid and 45 of potash; and since the yield of the general crop is larger on the average than one of white potatoes, a liberal supply of the minerals must in all cases be provided. The studies made of this crop have not yet established the best proportions of the constituents in fertilizers, though such experiments as have been conducted show that those that contain a very considerable excess of potash over the other elements are preferable. While nitrogen is needed, too much, particularly in soluble forms, seems to encourage too large a growth of vine, which contributes to yield, but at the expense of quality, which is a very important consideration. The best growers use fertilizers containing a small percentage of nitrogen and a high percentage of phosphoric acid and potash. Applications that furnish 20 pounds of nitrogen, 50 of phosphoric acid and 80 of potash to the acre have given excellent results in regions in New Jersey in which market quality up to a certain point is quite as important as increase in yield, though, of course, yield

is also considered. Any excess of nitrogen over this amount seems to contribute toward a larger, rather oblong, rooty growth of tuber, and to injure cooking quality. In growing crops for the general market, however, larger applications of nitrogen are demanded, and experiments have shown that organic forms are preferable to soluble forms, though the climate and season largely influence this point. In northern sections, and in cold seasons, the soluble forms are more useful than in the warmer climate and longer seasons of the South.

There is no question, however, that commercial fertilizers can be depended upon to produce maximum crops of sweet potatoes, and at much smaller cost than with yard manure.[1] Results reported by the Georgia Experiment Station[2] indicate the following formula as an excellent one for sweet potatoes, though, as there stated, "the amounts that can be used vary considerably, depending upon the character of the soil — the richer the land in humus, the greater the quantity that can be safely used." "Thin soils will, of course, only stand very moderate manuring, and necessarily produce a very small yield." The formula consists of —

Acid phosphate	320 lbs.
Cotton-seed meal	360 lbs.
Kainit	640 lbs.

This formula will furnish about 25 pounds of nitrogen, 50 of phosphoric acid and 80 of potash, and, according to the bulletin, will produce a yield of potatoes from 200 to 400 bushels to the acre, depending upon the season and variety of potatoes planted. Experiments at the Georgia

[1] Bulletin P, New Jersey Exp. Sta.
[2] Bulletin No. 25, Georgia Exp. Sta.

Station also show that organic nitrogen (cotton-seed meal) is preferable to nitrate of soda as a source of nitrogen.

In making mixtures which furnish these proportions of plant-food, other nitrogenous organic materials furnishing an equivalent of nitrogen — as blood or concentrated tankage — may be substituted for the cotton-seed meal, if they can be purchased quite as cheaply; and muriate of potash, furnishing an equivalent of potash, may be substituted for the kainit, if it can be more readily obtained.

As already stated, however, this fertilizer is too rich in nitrogen for the production of the best quality of potatoes, as, for example, "Vineland Sweets," which command the highest prices in northern markets. The growers in that district use a fertilizer richer in the minerals; one containing —

Nitrogen	3%
Phosphoric acid	7%
Potash	12%

is very generally used, though reasonably heavy dressings of this are often further supplemented by applications of from 200 to 300 pounds of acid phosphate and 100 to 150 pounds of muriate of potash to the acre.

The application of the fertilizers.

Owing to the fact that the sweet potato is grown from plants or slips, rather than from seed, and the fact that the best quality of potatoes is produced upon rather light, sandy land, it is desirable that the fertilizer should be applied some time before the putting out of the plants. The practice on this light land is to apply the fertilizer when making up the hills, which usually occurs from two to three weeks before the plants are set. That is, in making

up the hills, the soil is ridged, and during the preparation of the ridge the fertilizer may be distributed in it and well mixed with the soil. Where the land contains more clay and humus it is frequently advocated that the potash manures be applied broadcast the previous year, and only the nitrogenous fertilizer and superphosphate be applied immediately to the plant. On soils of this latter character, this is doubtless the best system. If kainit — which has been found to be preferable to muriate in the Georgia experiments referred to — is used as the source of potash, it is very necessary that it be well mixed with the soil before setting out the plants. Heavy applications of this salt in the spring proved injurious in the experiments conducted at the New Jersey Station. The effect of fertilizers upon the chemical composition of the tuber was chiefly to reduce dry matter, and not apparently to affect edible quality, though the experiments were carried out upon the general crop rather than upon those grown for high quality.

TOMATOES

Tomatoes are largely grown as a field crop, and the object of their growth, whether for the early market or for the canneries, is a factor that must be considered in the adoption of systems of fertilization.

Field experiments with fertilizers for tomatoes.

The impression is very prevalent among growers that the tomato does not require heavy manuring. Studies made at a number of experiment stations show, however, that the tomato is a plant that quickly and profitably responds to the use of manures or fertilizers, and that the maturity and yield are very largely influenced by the

method of manuring and fertilizing. Experiments were conducted by the New Jersey Station upon three farms located in different parts of the state, and during four seasons, the object of which was to test the effect on maturity and yield of the early crop of the use of nitrate of soda in different quantities and at different times, both with and without the addition of the mineral elements, phosphoric acid and potash, and to make a comparison of these with barnyard manure. The results showed:

1. That nitrate of soda was one of the best nitrogenous fertilizers for this crop, and that its use in small quantities (160 pounds to the acre), or in large quantities (320 pounds to the acre) in two applications, increased the yield materially, but not at the expense of maturity, and that this was equally true when used alone and when used in connection with phosphoric acid and potash.

2. That nitrate of soda, when used in large quantities (320 pounds to the acre) in one application, in the presence of a sufficient excess of phosphoric acid and potash, did increase the yield, but at the expense of maturity.

3. That when properly used, nitrate of soda was a profitable fertilizer for the crop.

It was shown, furthermore, that nitrate of soda was superior to both barnyard manure and mineral fertilizers alone, and on the whole, was but slightly less effective than the complete fertilizers.

Fertilizers for the early crop for different conditions of soil.

These results have been practically confirmed both by the experiments of the stations referred to, and also in actual practice on soils similar in character; namely, those which were well adapted for the early tomato — light, well-drained sandy loams (see Fig. 20, Plate X)

— and which had been previously well manured for crops entering the rotation. The results do not apply in the case of very poor soils, or upon heavy clay soils, which are not adapted for the early crop.

The statement that it pays to fertilize early tomatoes, and that nitrate of soda is one of the best fertilizers for the crop, must therefore be accompanied by statements regarding the condition of soil and the purpose of growth. With the conditions clearly understood, a scheme of fertilization for early tomatoes may be outlined which, when the conditions are observed, will be likely to give much better results than methods of fertilization which do not take into consideration the habits of the plant and the special object of its growth.

For example, on soils which have been well supplied with phosphoric acid and potash by manuring and fertilizing previous to setting, a complete fertilizer containing sufficient nitrogen derived from nitrate of soda to start the plant nicely should be used. If as much as 80 pounds of phosphoric acid and 100 pounds of potash have been supplied, an application of 100 to 150 pounds of nitrate of soda alone may be used, followed by a side-dressing of 150 to 200 pounds of nitrate of soda after the fruit has set and grown to about the size of walnuts. Care should be exercised not to make the application at the time of setting too large, because too rank growth often causes the plants to shed their bloom. A single application at the time of setting the plants would, perhaps, under good seasonal conditions give results quite as good, though the heavier application of nitrate at one time may result, in certain cases, in the loss of nitrogen by leaching, since it is an extremely soluble salt. In this case a deficiency of food would result, and thus prevent normal development.

On soils which possess only good mechanical condition, and are very poor in plant-food, a heavier application of both nitrogen and the mineral elements will be required, in which case the following fertilization is recommended:

Previous to setting the plants, or at the time they are set, apply 75 pounds to the acre of phosphoric acid, preferably derived from superphosphate, and 100 pounds of potash, derived from muriate, and thoroughly harrow or cultivate into the soil; and at the time of setting apply around the hill 100 to 150 pounds to the acre of nitrate of soda. Three to four weeks later, make another application of from 100 to 150 pounds to the acre of nitrate of soda. Owing to the small bulk of nitrate, it should be mixed with dry soil or sawdust, in order to insure even distribution. The only precaution to be observed is to prevent its immediate contact with the plant roots. If these methods are practiced, the plant secures its nitrogen in an immediately available form at a time when it is needed, — when it is set in the field. There is thus no delay in growth, and because of the presence of an abundance of the mineral elements, no excessive growth of vine is encouraged by the use of the nitrate, as would be the case were the mineral elements absent. Inasmuch as the nitrogen is applied close to the plant, it is within the immediate reach of its roots; and because it is all in an immediately available form, which is used up rapidly, the tendency to late plant growth, which would be caused by a continuous supply of nitrogen, is not encouraged, and a normal and rapid growth and development of fruit results.

It is not stated that by this method of fertilization maturity is increased in the sense that the date of the first picking is earlier, but that a larger number of fruits is picked earlier. It was not shown in any of the experiments

that the date of picking was made earlier by virtue of the nitrate, for, in fact, the earliest tomatoes were picked upon land where the minerals only had been applied. Here the yield was not satisfactory, but where the nitrate was applied, because of the larger crop, a larger proportion of early tomatoes was secured. It is obvious that, inasmuch as the price of the fruit rapidly declines as the season advances, receipts from the proportionately larger quantity of early fruit will be materially increased.

The use of fertilizers with yard manures.

When it is desirable to use yard manures with fertilizers for tomatoes, because of the abundance and cheapness of the former, they should be applied broadcast, and the nitrate applied at the time of planting, as already described, rather than both together in the hill. The tendency in the latter case will be to cause a loss of nitrogen from the nitrate, depending upon the amount of organic matter in the manures. That is, experiments and experience have shown that under these circumstances more or less of the nitrogen in the nitrate may be lost.

In the use of yard manures for early tomatoes, the application of excessive quantities should be avoided, as they are virtually nitrogenous manures, which, because of their organic character, feed the plant in proportion to their rate of decay. Hence, the presence of large quantities will encourage not only an undue growth of plant, but a late growth as well. The mineral fertilizers, as acid phosphate and muriate of potash, can be used with the yard manures with perfect safety, in fact, with great advantage, because they supplement the proportionate lack of mineral constituents. It is also desirable, where it is the practice to use manure, particularly if it is coarse,

to spread it during the winter, in order that the soluble portions may become thoroughly distributed throughout the soil. As soon as the land is ready to work in the spring, it should again be plowed shallow and then deeply tilled, in order both to thoroughly warm up the soil, and to incorporate with it coarser portions of the manure.

Upon light, sandy soils coarse manure may be used, provided it is spread broadcast some time before working the soil; whereas, upon heavy, cold soils, well-rotted manure should be used and its application confined to the hill.

Fertilizers for late tomatoes.

In manuring and fertilizing for the late crop, the character of the crop and the season of its growth should be remembered. In the first place, the plants for this crop are not put in the soil until summer, when the conditions are most favorable for the rapid change of organic forms of nitrogen into nitrates. Thus, if the soil has been manured or is naturally rich in vegetable matter, the additional application of nitrogen in immediately available forms is not so important. In the second place, the object of the growth is not early maturity, but the largest yield of matured fruit; hence it is more desirable to grow a larger plant than in the case of the early tomatoes. The fertilization should therefore be such as to furnish an abundance of all the elements of plant-food; and, inasmuch as the tomato belongs to the potash-consuming class of plants, any fertilization should be particularly rich in this element. It is not to be understood, however, that it is not necessary to apply nitrogen, for frequently soils are used that are either not well adapted for the plant or are poor, not having been previously well supplied

with vegetable matter containing nitrogen. On such soils, additional applications are very important, and nitrate of soda is one of the best forms to use, as it is absorbed freely by the roots, encouraging an early and vigorous growth of plant and a normal development of fruit. Slow-acting organic forms of nitrogen, on the other hand, frequently begin to feed the plant and cause its rapid growth when the energies should be concentrated in the growth and maturity of fruit. Fertilizers that have proved very excellent are those which contain a relatively smaller amount of nitrogen than is required for early tomatoes, and are richer in phosphoric acid and potash.

A study of the composition of both the fruit and vine of the tomato will serve to guide us in this respect, though the amounts and proportions of food removed by any crop are not absolute guides, inasmuch as the soil may furnish more of one constituent than another, and because the plant may have the power of acquiring certain of its constituents more readily than others. The analyses of the fruit and vines of tomatoes show that one ton contains:

	Nitrogen, Lbs.	Phosphoric Acid, Lbs.	Potash, Lbs.
In fruit	3.20	1.00	5.40
Vines (green)	6.40	1.40	10.00

Ten tons of the fruit, with the accompanying vines, which would probably reach four tons, would contain 57 pounds of nitrogen, 16 of phosphoric acid and 94 of potash. On a good soil, therefore, which without manure would produce five or six tons, there should be added a sufficient excess of the constituents to provide for a maximum production, and the materials should be relatively

richer in nitrogen and potash than in phosphoric acid. A mixed fertilizer composed of:

Nitrate of soda	300 lbs.
Bone tankage	500 lbs.
Acid phosphate	800 lbs.
Muriate of potash	400 lbs.

would contain, approximately, 75 pounds of nitrogen, 156 of phosphoric acid and 200 of potash in each ton. An application of 1000 pounds to the acre of this mixture would furnish nearly half as much nitrogen as is contained in a crop of ten tons, a surplus of phosphoric acid, and an equal amount of potash. Hence a dressing containing the amounts, kinds and proportions of plant-food here shown would be regarded as very desirable, since one-half of the nitrogen is in the form of a nitrate, which would contribute to the immediate growth of the plant. The amount of soluble and available phosphoric acid is sufficient to satisfy the needs of the crop throughout its entire growth, and such an abundance of potash as to contribute to the normal development of both plant and fruit. Formulas of this character have been used with good results, though the large proportion of salts sometimes make mixtures of this sort too moist to handle well, in which case a part of the potash, or even of the nitrate, may be applied separately with advantage. On poorer soils, the artificial supply of plant-food should be proportionately greater, or sufficient to provide for the entire needs of a fair-sized crop, since as a rule the relative power of the plant to acquire food is somewhat slighter on poor soils than on good soils; or, stated in another way, the results from the use of fertilizers are proportionately better upon soils in good condition than upon those not well cared for. A good formula for these may consist of:

Nitrate of soda	500 lbs.
Bone tankage	500 lbs.
Acid phosphate	400 lbs.
Muriate of potash	600 lbs.

One ton of this mixture would furnish, approximately, 105 pounds of nitrogen, 120 of phosphoric acid and 300 of potash. The application of 1000 pounds, therefore, would furnish the food in sufficient abundance and in good proportions to meet the demands of a fair crop. There is a contention prevalent among large growers of late tomatoes that ammonium sulfate as a source of nitrogen causes injury, and it is thought best to omit it even though there are not reliable experiments to prove this contention.

The advantage of using so large a proportion of nitrogen in the form of nitrate of soda in this case is, that it is immediately available, inducing the immediate and rapid growth of plant, and preventing a too late growth by furnishing a minimum of organic nitrogen, which would become available late in the season. The cost of the fertilizer suggested in these cases is high, and the necessity of so expensive a dressing could be materially reduced by decreasing the need for nitrogen, particularly in organic forms, which may be accomplished by showing crimson clover with or after the previous crop of, say, corn or tomatoes. If weather conditions are favorable, crimson clover may be sown in the tomato fields in August, after cultivation has ceased, or at the last cultivation, and a crop of clover grown which will provide nitrogen for the next year's crop. This method is now practiced with advantage by many growers. The late crop, like potatoes and sweet potatoes, is usually grown in rotations in which it is the chief money crop; hence the unused residue from

fertilizers applied in large amounts, as here indicated, contributes largely to the economical growth of subsequent crops. (See Fig. 21, Plate X.)

PEPPERS AND EGGPLANT. (See Fig. 22, Plate XI.)

It is not an uncommon practice to grow peppers and eggplant as a special crop under field conditions upon small farms, and often these plants may be seen occupying the same field. With these plants it is important that a liberal supply of quickly available nitrogen be supplied early in the growing season to produce early growth and strong foliage, although an excess should be avoided. It is a good practice to derive one-half of the nitrogen from quickly available organic materials. Before transplanting, the soil should receive not less than 1000 pounds of a mixture composed of

Nitrate of soda	200 lbs.
Dried blood, 16% am.	150 lbs.
Dried fish	150 lbs.
Acid phosphate	1100 lbs.
Muriate of potash	400 lbs.

As soon as the plants are well established, a side-dressing of nitrate of soda should be used and immediately worked into the soil. This practice may be repeated twice or three times and the amounts to apply fixed accordingly. Upon light soils well-rotted yard manure may be used advantageously, especially when well worked into the soil.

PEAS AND BEANS

In canning sections, peas are grown upon large acreages and followed by bush beans. It is often the practice to

grow them year after year upon the same soil, and under such conditions it is necessary to give special attention to the fertilization. Because both crops are legumes, little nitrogen is needed except during the early stages of growth to start the plants well. For peas the nitrogen should be derived largely from available sources, 75 pounds of nitrate of soda, 400 of acid phosphate and 100 of muriate of potash should supply the needed plant-food. The beans which follow should thrive upon the residual fertility elements, but it is often well to make an additional application of 400 or 500 pounds of a mixture high in the mineral elements and deriving its nitrogen almost entirely from organic sources to prolong the period of growth. It should be remembered that these crops thrive best upon soils rich in organic matter, and it is a good plan to return the vines to the soil.

FIELD BEANS

Field beans, often called white beans, are grown extensively for the food-stuffs market. This crop should be given different treatment than the garden bean because it is grown for the mature seed and the growing period is much longer. When grown in a rotation of beans, wheat and clover, little nitrogen need be used. When corn is included in the rotation, more nitrogen should be applied. In general, no less than 400 pounds of a mixture composed of

Nitrate of soda	200 lbs.
Dried blood	100 lbs.
Acid phosphate	1300 lbs.
Muriate of potash	400 lbs.

should be used to the acre.

GENERAL CONSIDERATIONS

The foregoing crops differ materially from one another in many respects, though they are all heavy potash feeders. They are considered here primarily as special crops produced upon general or dairy farms; hence, it must be remembered that there are numerous factors which influence the fertilization, chief among which are: the kind of soil, the rotation and system of fertilization and the length of growing season required by each.

CHAPTER XIV

GREEN FORAGE CROPS

A LARGE number of crops is included in this class. In dairy districts they are grown for summer feeding, mainly to supplement or to substitute pasturage entirely, as well as to provide a succulent ration of roughage in winter. Any crop which grows quickly, is palatable and makes a reasonably large yield, is adapted for the purpose. For convenience of study, these crops may be further classified into four groups: 1. cereals and grasses; 2. clovers and legumes; 3. cole crops or the cabbage tribe; 4. roots and tubers.

CEREALS AND GRASSES

In the case of those included in the first group, the purpose or object is to obtain as large a growth of leaf and stem as possible. Thus the character of the fertilization may differ from that recommended when the same crops are grown for the primary purpose of obtaining the largest yield of seed or grain. These crops, too, may in all cases be considered as only well adapted for the "intensive" system of practice — that is, when the management is such as to encourage the largest yield possible to the unit of area under the existing conditions of climate and season. The natural fertility of the soil thus becomes a less important factor; indeed it cannot

PLATE XII. Fig. 23. — Oats and Canada Field Peas respond to Good Fertilization.

be relied upon altogether, as the largest yield of succulent food is dependent upon a rapid and continuous growth, and hence the supply of plant-food must be relatively much greater than is the case when the cereals are grown for their seed. That is, forage crops, because succulence is a factor influencing quality, must, as a rule, be grown quickly, and in order that large yields may be obtained in a short period of time a relatively greater abundance of plant-food must be at their disposal than when the growth is distributed through a longer period. Besides, larger amounts of all of the food constituents are required for the production of the same amount of dry matter to the acre than when grown for the mature crop, because the dry matter of the mature crop is richer in the constituents derived from the air and poorer in those derived from the soil, than the dry matter of the immature crop.

Maize (corn) forage.

A valuable forage crop of the first group is maize (Indian corn), because it grows quickly, is well adapted to a wide variety of soils and climates, is extremely palatable, and is capable of producing large yields. The fertilization which has been recommended for the field crop is less desirable than one which furnishes a greater proportion of nitrogen, because of the greater need of this element, and because it encourages a larger leaf and stalk growth; and the greater the proportion of these in a corn crop, the richer will be the dry matter in the important compound protein, and nitrogen is the basic element in this group of nutrients.

When the crop is grown on good land on clover sod, which has been liberally manured, the fertilizers applied

should be particularly rich in the mineral elements, phosphoric acid and potash. An application of 500 pounds of a mixture containing —

Nitrogen	2%
Available phosphoric acid	6%
Potash	8%

would provide an abundance of food, even should unfavorable conditions intervene, but when grown on light, unmanured soil without sod, a larger amount of nitrogen should be used in connection with the minerals. An application of 25 pounds of nitrogen, 35 of phosphoric acid and 50 of potash is as small a fertilization as should be recommended on soils of this character, since a yield of 10 tons to the acre, containing 25 per cent of dry matter, — which is only a fair crop, — would remove 60 pounds of nitrogen, 25 of phosphoric acid and 70 of potash. Hence, very large increases in yield could not be expected from smaller dressings, unless conditions were absolutely favorable throughout the entire period of growth. The nitrogen, as in the case of field corn, may be derived from organic sources, as the season of growth is the same, — the summer, — which is the most favorable for encouraging a rapid change of the organic nitrogen into the soluble nitrates. The phosphoric acid should be in large part derived from superphosphates, though since the season of growth and the character of the crop and of its cultivation are conditions all of which favor a rapid change of insoluble into available forms, a portion may be supplied by ground bone or tankage. The potash may be kainit or muriate, though if kainit is used, it should be broadcasted and well worked into the soil before planting.

Silage corn.

Corn grown for the silo, while distinctly a forage crop, is, in its management, very similar to the field crop, and is not planted so thickly as to prevent the formation of ears. The object in its growth is, however, to obtain a large yield of dry matter, somewhat richer in nitrogenous substance and poorer in starch and woody fiber than field corn. Hence the fertilizers for the crop on medium soils should be richer in nitrogen than for the field corn, where the primary object is the grain, and where heavy fertilization with nitrogen would encourage a disproportionate stalk growth. An application of 30 pounds of nitrogen (equivalent to 250 pounds of dried blood or 450 of cottonseed meal), 40 of phosphoric acid (equivalent to 300 pounds of acid phosphate) and 60 of potash (equivalent to 120 pounds of muriate of potash) would provide for a marked increase in yield.

Wheat and rye forage.

In the growth of cereal grains, the object is to secure as large a yield of grain as is possible under the conditions of climate and season, and only such development of leaf and stem as will contribute to a maximum yield of grain. Hence a too liberal nitrogenous fertilization which encourages this form of growth may result in too great a proportionate yield of straw. This objection becomes an advantage when the cereals are grown for forage.

The cereal crops, wheat and rye, if seeded in the fall, should therefore receive a fertilizer which shall especially promote leaf and stem growth; and to accomplish this purpose in the best manner, a rapid early fall growth, and a consequent deep rooting system, as well as an

early and rapid spring growth, should be encouraged. Fertilizers most suitable are rich in nitrogen and phosphoric acid, and should contain potash also, if the land has not been previously well supplied with this element. The larger proportion of the nitrogen, however, should be applied in available forms as a top-dressing in the spring, rather than at time of seeding, thus reducing the possible loss of this element during the winter and early spring through leaching, besides providing the plant with it when most needed, and producing a crop richer in nitrogenous substance.

The ranker growth and somewhat coarser product resulting from this method of fertilization, while not desirable for grain crops, is not a detriment when the product is cut in its green stage for feeding, and the larger growth is accompanied by greater succulence.

Where these cereal grains are sown mainly as catch crops following a corn crop which has been liberally fertilized with the minerals phosphoric acid and potash, the application at time of seeding may be light, and may consist only of nitrogen and phosphoric acid, — for example, from 200 to 400 pounds to the acre of a dissolved bone; and the top-dressing in the spring need not exceed 100 pounds of nitrate of soda to the acre for the wheat, and 75 pounds to the acre for the rye. For lighter soils, or for those not previously well fertilized, much heavier applications not only are required, but all of the constituents should be included, and the top-dressings should be made in the spring, as already pointed out.

Spring rye.

For spring rye, an application of a fertilizer furnishing 10 pounds of nitrogen, 20 of phosphoric acid and 10 of

potash to the acre would be a sufficiently liberal dressing for the crop on good soils, since the plant possesses good foraging powers, though it is not so desirable a forage crop for northern climates as the winter rye. The nitrogen, in any case, should be in quickly available forms.

Oats.

Oats and millet are also suitable crops for forage purposes, and are largely grown; the first, because it is adapted for cool, moist weather, and makes a rapid early growth, and the second, because adapted for late spring seeding and for summer conditions.

The oat crop for forage purposes is even more generally benefited by manuring than when grown for the grain, and the constituents particularly useful are nitrogen and phosphoric acid, though on sandy soils, and on those of medium fertility and not previously fertilized with potash, this element should also be added.

A good dressing, keeping in mind the value of the possible increased yield, may consist of 12 pounds of nitrogen, 20 of phosphoric acid and 10 of potash, — the nitrogen largely in the form of a nitrate and the phosphoric acid in soluble and available forms.

The oat crop is peculiar in that shortly after the germination of the seed there usually occurs a period of a week or ten days during which the growth is extremely slow, which experienced farmers call the "pouting" period. While the exact cause of this well-known habit is not understood, it is believed to be due in part to the absence of an available plant-food of the right sort early in the season, since liberal applications of nitrates and superphosphates seem to shorten the period of "pouting," if not altogether preventing its occurrence. Its avoid-

ance for grain crops, while important, is not so important a matter as in the case of forage crops, since an extension of the period of growth simply delays ripening, while in the latter, delays not only prevent maximum growth within a certain time, but seriously interfere with rotations.

Winter oats, which are successfully grown in the southern sections of the country, should be fertilized at time of seeding practically in the same manner as wheat; that is, dressings furnishing small amounts of nitrogen and considerable phosphoric acid, to be followed in spring with a top-dressing of nitrate of soda, not to exceed 100 pounds to the acre.

Oats and peas.

Where oats are grown with field peas for the purpose of supporting the vines, as well as to obtain a larger yield than from either alone, the fertilizer should also contribute toward the increase in the pea crop, and hence a greater abundance of the minerals should be applied, though it is very desirable in this case, too, to encourage the rapid growth of the oats by reasonably liberal supplies of available nitrogen. (See Fig. 23, Plate XII.)

Barley and peas.

The growth of this combination of plants is a desirable one when late fall forage is needed, and as a crop, is well adapted for fall conditions. The fertilization should be liberal, in order to encourage a rapid and large appropriation of food, which may be elaborated after light frosts occur. An application of 200 pounds to the acre of a mixture of 100 pounds of nitrate of soda, 175 of acid phosphate and 25 of muriate of potash will furnish sufficient and good proportions of the plant-food constituents.

Millet.

The various kinds of millet are eminently surface feeders, and are particularly benefited by liberal applications of all the fertility elements. In fact, maximum forage crops of this plant cannot be obtained except when there is present in the soil such an abundance of all of the fertility elements as to enable a continuous and rapid growth. Both the nitrogen and phosphoric acid should be largely in immediately available forms; hence nitrates and superphosphates are recommended. The potash may be in the form of muriate. A crop of ten tons to the acre of millet forage, of any of the Japanese varieties, which are very suitable for this purpose, will remove 50 pounds of nitrogen, 25 of phosphoric acid and 110 of potash, practically all of which food is absorbed from the immediate surface soil. Good crops frequently reach this assumed yield; hence, unless the land is in a high state of fertility, or has been previously fertilized, it is necessary, in order to obtain a fair crop, to furnish by direct application at least one-half of the nitrogen and potash, and as much phosphoric acid, as are contained in the crop. These amounts and kinds of plant-food could be practically supplied by a dressing of 450 pounds of a mixture made up of 150 pounds of nitrate of soda, 200 of acid phosphate and 100 of muriate of potash, and such dressings have given excellent satisfaction in the New Jersey experiments with forage crops.

Orchard-grass.

Orchard-grass is among the earliest grasses that are useful for soiling or for pasture. It possesses many valuable characteristics, and is worthy of more careful

attention than is usually accorded it. Its chief advantage lies in the fact that it is ready for use two or three weeks earlier than the grasses ordinarily grown; it is a plant, also, that makes a very heavy growth under good conditions of soil and season.

Like other grasses, orchard-grass requires an abundance of available nitrogenous food, and therefore the promise of a crop is very much increased by the application of manures or fertilizers containing nitrogen at the time of seeding, and by top-dressing with nitrate of soda in early spring. A good formula or mixture for time of seeding is the following:

Nitrate of soda	100 lbs.
Tankage	200 lbs.
Acid phosphate	600 lbs.
Muriate of potash	100 lbs.

An application of 400 to 600 pounds of such a mixture well harrowed into the soil with a spring top-dressing of 100 to 150 pounds of nitrate of soda should amply supply the requirements of an abundant crop.

Italian rye-grass.

Another grass that has received some attention as a forage crop, particularly for summer pasture and soiling, is Italian rye-grass. It is especially suitable for moist soils, or for soils that can be irrigated, and responds very profitably to the application of water or heavy fertilization. The fertilization of this crop may be the same as that recommended for orchard-grass, except where irrigation is practiced, in which case less available nitrogen should be used because it is likely to be lost by leaching.

Bermuda-grass.

In the southern states, Bermuda-grass is considered one of the most valuable grasses for pasture. It is distinctly a hot weather plant, and thrives only in those regions which have short, mild winters. Fortunately, it is well adapted for pasture on poor lands, and its power of withstanding a drought is one of its valuable characteristics. Because it is capable of producing a new plant at each joint, it spreads rapidly, and it is this quality which makes it a valuable pasture grass as well as an aggressive and pestiferous weed. However, it can be eradicated from a field where it is not wanted with comparative ease by proper cultivation. At the time of seeding, the soil should be well supplied with minerals, and top-dressings of nitrate of soda should be made in spring.

CLOVERS AND OTHER LEGUMES

There are four types of true clover — red clover and mammoth red clover, a variety of the former, alsike clover, crimson clover, white clover — which are among the most valuable of our summer forage crops: first, because of the time of their growth, they furnish food before spring-sown crops are ready; second, because of their power of acquiring food from sources inaccessible to the cereals, they are less exhaustive; and third, they are especially rich in the compound protein, the most useful substance contained in feeds. Since these crops generally grow well on soils of medium fertility, many are inclined to regard them as able to subsist and make a good crop without liberal fertilization. It should be remembered, however, that the power which these plants possess of acquiring

nitrogen from the air depends largely upon the supply at their command of the mineral elements, phosphoric acid, potash and lime; the presence of these is of primary importance, and good crops cannot be grown on land deficient in these elements. In any event, therefore, liberal supplies of the minerals should be provided, in order that maximum yields may be obtained. (See Fig. 24, Plate XI.) On soils of medium fertility which are fairly well supplied with vegetable matter, the need for nitrogen is not marked, even in the early growth of the plant. On lighter soils, however, a nitrogenous fertilization is often serviceable, because supplying nitrogen before the plant has acquired the power of obtaining it from the air. This practice enables the plant to make an early start, and prevents the delay in growth which sometimes occurs, particularly on light soils, during the period immediately after germination, when the plant is unable to obtain its nitrogen from sources other than the soil. A green forage crop averaging 10 tons to the acre requires, on the average, about 30 pounds of phosphoric acid and 100 of potash, and the nitrogen which necessarily accompanies these amounts of minerals will reach, on the average, 100 pounds. If this element is drawn from the air, because provided with an abundance of minerals, it is manifestly economy to supply the full amount of these required, rather than omit them, and thus to limit the plant's power of acquiring this expensive element, since the value of the 100 pounds of nitrogen gained is greater than the cost of both the phosphoric acid and potash required. The fertilization of these various clovers may be much the same; in general an application of 200 pounds of acid phosphate and 100 of muriate of potash should be sufficient, especially if they follow a well-fertilized crop, such as potatoes.

Japan clover.

Japan clover, though not a true clover, is valuable as a pasture crop because it is well adapted to poor and light lands and withstands drought well, growing and spreading when other plants die for lack of moisture. It thrives from Virginia southward and as far west as Kansas. It is seldom fertilized, even though it is much like other clovers and responds to liberal applications of the minerals.

Cowpea and soybean.

The clovers, which range in their length of life from annuals to perennials, are, too, able to obtain their necessary supplies of minerals more readily from soil sources than the distinctly summer crops, as the cowpea and soybean, because of the longer period of preparatory growth in the case of the former. That is, clover or vetch, while it does make a very rapid growth through a short period, does not obtain all of its food during that period. In its preparatory stage of growth — fall and early spring — a very considerable amount of food, the larger proportion, in many instances, is obtained, which in its later stages of growth is simply distributed throughout the entire plant; while the cowpea and soybean, on the other hand, must obtain the entire amount of food needed for their growth and development during a short period, and these crops reach their best stage of development for forage in two and one-half to three months from time of planting. Hence, these crops, which possess apparently greater foraging powers, and make their development during the season when conditions are most favorable for rapid change of insoluble to soluble food in the soil, require, when the conditions of the land are the same in each case,

a relatively greater abundance of the mineral elements than do the clovers, which can acquire food through a longer period.

An application of 300 pounds to the acre of a mixture of 200 pounds of acid phosphate and 100 of muriate of potash, which supplies 25 pounds of phosphoric acid and 50 of potash, would, on medium soils, be regarded as a sufficient annual dressing for clover crops; whereas, in the case of the purely summer crops, the application could be increased one-half with profit. In the case of the summer crop, the phosphoric acid should be in a soluble form, because it is not economy to depend upon the conditions of climate, soil and season to change insoluble forms rapidly enough to provide for the contınous feeding of the plant, while for the clovers, less available forms may be used with advantage.

Spring vetch.

Spring vetch may be substituted for Canada field peas in a mixture with oats; and in the northern states, where the pea-louse has been very destructive, it serves an excellent purpose. It is sown in spring or early summer, and does not survive the winter. The preparation of soil and fertilization should be practically the same as recommended for oats and peas.

Hairy or winter vetch.

Hairy vetch is used extensively as a cover-crop or green-manure, and its use in combination with wheat or rye as a forage crop is increasing rapidly. The chief advantage of the use of hairy vetch with wheat or rye lies in the fact that a larger crop of forage may be secured than when the cereal is grown alone. The fertilization should be the

same as recommended for the cereal with which it is grown, except that the amount of nitrogen may be slightly reduced. A liberal supply of minerals should be applied.

Alfalfa, or lucerne.

This valuable crop, which was not formerly regarded as well adapted for the eastern states, can be successfully and profitably grown if the soil is sufficiently deep and open and naturally well drained, and provided it is supplied with an abundance of mineral food, consisting of phosphoric acid, potash and lime. Its habits of growth are such as to enable the harvesting of three or four green forage crops, and at least two hay crops annually. In order to meet the large plant-food demands thus made, the fertilization previous to seeding must be not only liberal, but frequent top-dressings should be made. The phosphoric acid for these dressings should preferably be drawn from superphosphates, in order that ready distribution may be accomplished, while a large portion of that contained in the preparatory dressing may consist of the less soluble forms, as ground bone, natural phosphatic guanos, and fine ground rock phosphates.

Twenty tons of alfalfa green forage, which may be regarded as a good annual yield for this plant from the two to four cuttings that may be made, will contain 250 pounds of nitrogen, 50 of phosphoric acid and 275 of potash. Assuming that the demands for soil nitrogen are confined to a short period immediately subsequent to the germination of the seed, the total required plant-food is still considerable, and is especially severe upon the potash compounds of the soil. Hence, the fertilizers supplied should be particularly rich in this element. For eastern conditions, where soils possess a medium rather than

a high potential fertility, heavy dressings of the minerals should always be made. A good preparatory fertilizer may consist of 20 pounds of nitrogen, equivalent to 125 pounds of nitrate of soda; 75 of phosphoric acid, equivalent to 600 of acid phosphate; and 200 of actual potash, equivalent to 400 pounds of muriate of potash to the acre; and annual top-dressings should provide at least 30 pounds of phosphoric acid and 100 of actual potash for the same area.

Inasmuch as careful preparation of soil is necessary previous to seeding, and since this can preferably be accomplished by the growth of cultivable crops, the fertilizers may be also partly applied to these rather than all at once immediately preceding the seeding, thus limiting danger of injury to germination by an application of so large a proportion of salts.

Sweet clover.

The use of sweet clover is spreading very rapidly in the United States. While its growth and purpose of growth are very much the same as alfalfa, it does not seem to require nearly as much fertilization, and it is not uncommon to produce enormous yields of forage or hay upon good soils without any fertilization. Its culture may be the same as alfalfa, but it has been found more profitable in most localities to sow it in grain in spring when the ground is honeycombed. In this case no fertilization is needed. If sown alone, moderate quantities of the minerals should be supplied. It thrives especially well in hard, compact soils, rich in lime.

Need of lime for legumes.

Another point that should be remembered in the fertilization of the leguminous plants is their need for

lime. This is true of the clovers particularly, not only for the purpose of providing the plants with a sufficient amount of this element, but in order that any possible acidity of soil may be corrected, since the bacterial life in the soil, which is essential in order that the plant may acquire its nitrogen from the air, is discouraged rather than encouraged by the presence of acid. Hence, all soils that are used for the frequent growth of leguminous crops should receive a dressing of lime, preferably in the fall; 25 bushels of stone lime to the acre, or its equivalent of ground limestone. Once in four or five years is a sufficient amount for medium soils.

Fertilization of soiling crops.

The necessity for fertilization, and the method employed in "intensive" practice, are illustrated by the following scheme of growing soiling crops, now practiced at the Experiment Farm in New Jersey. If an abundance of food is not supplied, the continuous feeding and consequent constant and rapid growth of the plants, which are primary necessities of the system in order to maintain the rotation and to obtain maximum yields, are prevented. With proper management in other respects, the scheme of rotation and fertilization will result in a gradual increase in the fertility of the soil.

SCHEME OF SOILING CROPS

No. of Acres	Crop Rotation	Time of Seeding	Amount of Fertilizer Applied	Time of Harvesting
1	Crimson clover . .	Aug. 11, '97	100 lb. Acid phosphate 50 lb. Muriate of potash	May 20, '98
	Corn	June 20, '98	100 lb. Acid phosphate 50 lb. Ground bone 50 lb. Muriate of potash	Aug. 20, '98
	Barley and Peas .	Aug. 25, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Muriate of potash	Oct. 25, '98

No. of Acres	Crop Rotation	Time of Seeding	Amount of Fertilizer Applied	Time of Harvesting
2	Crimson clover	Aug. 24, '97	100 lb. Acid phosphate 50 lb. Muriate of potash	May 10, '98
	Corn	June 10, '98	100 lb. Acid phosphate 50 lb. Ground bone 50 lb. Muriate of potash	Aug. 10, '98
	Barley and Peas	Aug. 25, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Muriate of potash	Oct. 25, '98
3	Corn	May 20, '98	50 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Ground bone 50 lb. Muriate of potash	July 20, '98
	Millet	Aug. 1, '98	75 lb. Nitrate of soda 150 lb. Acid phosphate 75 lb. Muriate of potash	Oct. 1, '98
4	Corn	May 10, '98	50 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Ground bone 50 lb. Muriate of potash	July 10, '98
	Barley and Peas	Aug. 10, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Muriate of potash	Oct. 10, '98
5	Wheat	Sept. 28, '97	150 lb. Acid phosphate 50 lb. Ground bone 25 lb. Muriate of potash	June 5, '98
	Oats and Peas	April 20, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 25 lb. Ground bone 50 lb. Muriate of potash	June 20, '98
	Soybeans	Aug. 1, '98	200 lb. Acid phosphate 100 lb. Muriate of potash	Oct. 1, '98
6	Rye	Sept. 29, '97	150 lb. Acid phosphate 50 lb. Ground bone 25 lb. Muriate of potash	May 1, '98
	Millet	May 1, '98	75 lb. Nitrate of soda 150 lb. Acid phosphate 75 lb. Muriate of potash	July 1, '98
	Cowpeas	July 20, '98	200 lb. Acid phosphate 100 lb. Muriate of potash	Sept. 20, '98
7	Oats and Peas	April 10, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 25 lb. Ground bone 50 lb. Muriate of potash	June 10, '98
	Soybeans	July 1, '98	200 lb. Acid phosphate 100 lb. Muriate of potash	Sept. 1, '98
	Barley and Peas	Sept. 1, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Muriate of potash	Nov. 1, '98

No. of Acre	Crop Rotation	Time of Seeding	Amount of Fertilizer Applied	Time of Harvesting
8	Oats and Peas	April 1, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 25 lb. Ground bone 50 lb. Muriate of potash	June 1, '98
	Cowpeas	June 15, '98	200 lb. Acid phosphate 100 lb. Muriate of potash	Aug. 15, '98
	Barley and Peas	Aug. 20, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Muriate of potash	Oct. 20, '98
9	Rye and Vetch	Sept. 10, '97	25 lb. Nitrate of soda 150 lb. Acid phosphate 75 lb. Muriate of potash	May 5, '98
	Corn	June 1, '98	100 lb. Acid phosphate 50 lb. Ground bone 50 lb. Muriate of potash	Aug. 1, '98
	Barley and Peas	Aug. 15, '98	25 lb. Nitrate of soda 100 lb. Acid phosphate 50 lb. Muriate of potash	Oct. 15, '98

This scheme, which provides for two or three crops each season, has proved entirely practicable and successful when liberal fertilization is practiced, as here indicated.

THE CABBAGE TRIBE

Several members of the mustard family of the cabbage kind are useful forage crops, and their cultivation is rapidly increasing. In general feeding practice, they may be compared with root crops. In fact, kohlrabi is often classed with root crops, and well it may be, since it is very closely allied to the turnips and rutabagas, differing chiefly in having the thickened part above the ground rather than below ground. The leading cabbage-like forage plants are rape, cabbage and kohlrabi. The kales are not much grown for forage in North America. Their culture does not differ greatly from that of rape. Thousand-headed kale is the kind mostly recommended, but it does not appear to have any advantage over rape for forage.

Rape. (See Fig. 25, Plate XIII.)

Although rape does well in soils of medium fertility, the best results are secured when they are naturally rich, or have been well fertilized. When grown for forage, an application of barnyard manure at the rate of 8 tons to the acre, well worked into the surface soil, is desirable, because the plant is a voracious feeder. For its best growth it must have abundance of available nitrogen. Hence, if manures are not readily obtainable, an application of fertilizers rich in nitrogen should be applied. Experience has shown that a fertilizer containing

Nitrogen	5%
Phosphoric acid (available)	8%
Potash	9%

applied at the rate of 600 pounds to the acre, will supply the food in good proportions. Should the season be unfavorable for rapid growth, an additional application of 100 pounds to the acre of nitrate of soda when plants have well started will stimulate growth and help to insure a large crop. This top-dressing of nitrate of soda should be made when the plants are dry.[1]

Cabbage.

Among those forage crops grown for late use, there is none capable of producing the large tonnage which may be secured from cabbage when it is efficiently attended. It has not been grown to any extent in this country for feeding live-stock, but a knowledge of its value for this purpose is undoubtedly extending. It is a voracious

[1] Voorhees, "Forage Crops."

PLATE XIII. FIG. 25. — Dwarf Essex Rape mixed with Soybeans and Sweet Clover, and Heavily Fertilized, makes a Luxuriant Forage.

feeder, and if it is to be grown successfully for forage it should be liberally fertilized. Twenty to 25 tons of manure should be applied before plowing, 1500 pounds of lime after plowing, and just previous to seeding 100 pounds of nitrate of soda, 700 of acid phosphate and 200 of muriate of potash to the acre. It is important that these applications be uniformly made, and that the lime should not be omitted, because it is a safeguard against a disease known as club-root or finger-and-toe.

Kohlrabi.

Kohlrabi attains its best development when grown upon rich soils, and proves a valuable forage crop, especially because it may be fed at any period of growth without risk. It may be grown upon any soils suitable to rutabagas, and its culture and fertilization may be the same.

ROOT CROPS

These crops are, as a class, exhaustive of plant-food elements, much more so, in proportion to the dry matter contained in them, than the cereals or legumes. It will require, for example, 20 tons of topped fodder-beets or turnips to furnish as much total food as is contained in 10 tons of corn forage or silage, as the former seldom contain more than 10 per cent of dry matter, whereas the latter frequently contain more than 20 per cent; yet on the average, 20 tons of roots will contain 60 pounds of nitrogen, equivalent to 400 pounds nitrate of soda, 35 of phosphoric acid, equivalent to 300 pounds of acid phosphate, and 150 of potash, equivalent to 300 of muriate of potash, which amounts are far in excess of those contained in a corn crop, particularly of the minerals, phos-

phoric acid and potash. The nitrogen demands for the two crops are practically identical. In the case of both kinds of crops, these fertility constituents are obtained entirely through the roots from soil sources.

In respect to fertilization, however, the root crops may be divided into two groups, very similar in their demands for plant-food, the first to include mangel-wurzels, fodder-beets, sugar-beets and carrots, and the second turnips, swedes (rutabagas) and rape.

Fertilizers for fodder-beets, sugar-beets and carrots.

The first group requires that the fertilization with nitrogen and phosphoric acid shall be liberal, and that these constituents shall be applied in readily soluble forms, in order to meet the large and early demands of the plant for them. Potash is also a very essential constituent, particularly upon soils of a light, sandy character; upon clay loams the plant is better able to obtain this element.

In order to obtain a large amount of actual food by the growth of these crops, a large tonnage must be secured, and a large yield cannot be obtained unless provision is made for a continuous and rapid growth, and this again cannot be accomplished without an abundant supply of nitrogen and phosphoric acid, which, as already stated, are the elements which, more than any others, seem to rule the crop.

In the case of sugar-beets, the suggestion for fertilization when grown for sugar (Chapter XVII) may be followed in large part. That is, particular attention should be given to the supply of nitrogen and phosphoric acid, though when grown for forage it is important not only to secure sugar, which constitutes a large proportion of the

dry matter, but that the gross yield shall be much greater than in the former case. Hence, a liberal use of yard manure need not be avoided, and heavier dressings of nitrogen, which stimulates early leaf growth, may be made.

For both fodder-beets and sugar-beets, an application to the acre of 40 pounds of nitrogen, 50 of phosphoric acid and 100 of potash, or 1000 pounds of a fertilizer, containing —

Nitrogen	4%
Available phosphoric acid	5%
Potash	10%

should insure a very considerable increase in yield on soils of medium fertility, provided the elements are drawn from the best materials. On light soil the fertilization should be still heavier, and the proportion of nitrogen increased. In fact, on soils poor in fertility and possessing good physical qualities, the contributions of plant-food by them may be largely ignored, and the dressings made large enough to supply the entire amount of food required by the crop. On such soils the nitrogen should preferably be applied in fractional dressings and in quickly available forms, because it is essential that this element should be quickly absorbed by the growing plant. The minerals may be all applied in one dressing, though preferably in two, in order that the constituents may be well distributed throughout the surface soil. To better accomplish this, cultivation should follow each application.

Turnips and swedes.

In the case of the second class of crops, it has been shown that they are able to extract their phosphoric acid

from combinations not readily accessible to other plants. In fact, they respond so promptly to applications of this element that frequently too little attention is given to the supplies of the other elements; yet in order to obtain satisfactory yields, these must also be added. An analysis of the turnip, for example, shows it to be rich in potash; hence it must naturally be a voracious feeder upon compounds containing this element, and while it seems to obtain it more readily from soil sources than many other plants, these supplies should not be depended upon, even on good soils, to meet its entire needs in this respect. A liberal supply of nitrogen is also demanded, particularly during the early growth. An application of a fertilizer containing 20 pounds of nitrogen, derived in part from nitrate, 40 of phosphoric acid, derived in large part from phosphates, and 40 of potash, derived from muriates, would be a fair dressing on soils of good character. On the poorer soils, the application of the constituents of the same kind and forms should be very largely increased.

In these crops, as in those already mentioned, it is essential — and success depends upon this as much as upon any other factor — that the growth should be continuous; and in order that there shall be no delay in this respect, there must be an abundance of available food always at their command.

TUBER CROPS

In many sections the potato and sweet potato are grown for roughage. For these crops no different fertilization is recommended than that already outlined (Chapter XIII) for the crops when grown for market, though in the case of sweet potatoes, soils not adapted for the growth of marketable tubers may be used.

CHAPTER XV

MARKET-GARDEN CROPS

A KNOWLEDGE of the principles of plant nutrition is perhaps more serviceable in market-gardening than in any other line of farming. This branch of farming cannot be profitably conducted either without suitable soils or without an abundant supply of plant-food. Both of these conditions are essential for the growth of high-class products.

THE YIELD AND QUALITY DEPENDENT UPON CONTINUOUS AND RAPID GROWTH

In these days, it is not only the yield of a definite area that must be considered, but the edible quality of the products that are put upon the market. Quality depends upon, or is measured by, both appearance and palatability; and palatability is determined by the succulence and sweetness of the vegetable, or its freedom from bitterness, stringiness, and other undesirable characteristics which frequently exist, and which can be largely eliminated provided the grower is thoroughly familiar with his business, assuming, of course, that varieties are the same in each case. It has been demonstrated that market-garden crops of the best quality are those which are grown under conditions which permit of a continuous and rapid development. Any delay in the growth of a radish or of lettuce

is largely responsible for the sharp taste and pungent flavor of the former, and the bitterness and toughened fiber of the latter. The same principles hold true of early table beets and turnips. The beets become stringy and wiry in character, and are less palatable if during the period of normal growth there has been any delay. In a time during which there has been no progress the

FIG. 26. — GARDEN FERTILIZER SOWER.

The garden fertilizer sower has the advantage of concentrating plant-food in the row. This machine is very useful when several small applications of soluble constituents are made to young plants during the growing season, *because it places the plant-food within immediate reach of the roots.*

fibrous portion of the vegetable is toughened, and exists in too great proportion. In the case of the early turnip, if any delay in growth occurs, the quality is injured, and the peculiar, pleasant flavor, a characteristic of the perfect vegetable, is changed; it becomes unpleasant. The unfavorable conditions of growth seem to cause more or less reversion to the character of the original plant from which the improved type has been

derived, mainly through selection and improved methods of cultivation.

All these conditions of growth are not absolutely under the control of the grower; as, for example, a lack of sufficient moisture and sunshine, the latter of which is certainly beyond his power to control. But given good natural conditions in respect to soil, and a favorable season, the one thing that more than any other controls the yield and quality of market-garden products is plant-food of the right amount and kind. In other words, in crops of this sort, any limitation in this respect usually results in a disproportionate reduction in profits. Only under exceptional circumstances is it economical to depend upon natural soil conditions for profitable crops, however favorable such conditions may be, because in successful practice the cropping is in the highest degree "intensive," and even the best soils are liable to be deficient in some essential feature.

In market-gardening, two factors are essential: first, a soil that is capable of absorbing and holding water, without being so compact and tight as to prevent free movement of water in all directions. Probably a typical garden soil would be a sandy loam; this kind of soil, however, would be largely regarded as a good place for the plants to grow, rather than as an entire source of food required. Hence, the second factor is that the soil should contain an abundant supply of all kinds and forms of plant-food needed. This may be accomplished by the use of manures, preferably well rotted, which contain plant-food in more or less soluble forms, but which possess, in addition, decaying vegetable matter, so important in contributing to the physical character of soils, more especially in the matter of holding moisture. Hence, any soil well

adapted naturally for market-gardening should either be heavily manured, or should have been subjected to green-manuring for a sufficient period of time to build it up in vegetable matter. Owing to the cost, both in money and labor, of supplying the food requirements through the use of manures only, nowadays resort is made to commercial fertilizers; these not only supply the total food, but are capable of supplying them in such forms as to enable the plants to absorb them at once. That is, there is no necessity for any delay, in order that the plant-food constituents themselves may be made available. Fertilizers are therefore capable of supplying the needed requirements when other conditions are favorable, and may be grouped into three classes; *i.e.* general, specific and basic. That is, a general formula would be one that is not made for any specific crop, but which contains both soluble and insoluble forms of plant-food, with the idea of building up the soil in the constituents, rather than meeting the special requirements of any one crop.

The specific formula is one made up for the purpose of meeting a particular need of the crop at a particular time. These will be noted through the discussions of the various crops. A basic formula is one containing large quantities of all of the best forms of plant-food to be used as a base for supplying market-garden crops with their general needs, with the idea that amendments may be made of nitrogen, or of other constituents, as the conditions seem to require.

It might seem from the discussion thus far that for these crops the recommendations as to methods of fertilization might be briefly though fully expressed as follows:

Apply a reasonable excess of all of the essential fertilizer constituents to all of the crops. Nevertheless, because of

the peculiarities of growth of the different plants, as well as the different objects of their growth, distinctions should be made in reference to the kinds and amounts of plant-food applied, and these distinctions should be borne in mind, in order that the most profitable returns may be secured. Market-garden crops may, however, be grouped according to similarity, both in character and object of growth, and each group fertilized in a similar manner, which obviates the necessity of extra labor in the preparation of fertilizers.

A basic fertilizer for market-garden crops.

A good basic fertilizer for market-garden crops may consist of:

Nitrate of soda	250 lb.
Ammonium sulphate	100 lb.
Dried blood	150 lb.
Ground fish	100 lb.
Acid phosphate, 16% A.P.A.	1000 lb.
Sulfate of potash	400 lb.

A mixture of these materials of standard quality would show an average composition of 4 per cent nitrogen, 8 per cent phosphoric acid and 10 per cent potash. Such a mixture is an excellent basic formula for such crops as asparagus, cucumbers, onions, cabbage, cauliflower, celery, eggplant, melons, peppers, squashes and the like, but any mixture of the composition 4–8–10 which supplies the plant-food constituents in good forms may be used as a basic formula for all market-garden crops, leaving the specific needs of the different plants to be met by top-dressings, or applications of the other constituents. The fertilizer ingredients, nitrogen and phosphoric acid, should preferably consist of the different forms, rather than to

be all of one form, though the cost of the element will naturally regulate this point to some extent. That is, a part of the nitrogen should be nitrate or ammonia, and a part organic; a part of the phosphoric acid should be soluble (from superphosphates), and a part insoluble (from ground bone, tankage or natural phosphates). The solu-

FIG. 27. — GARDEN FERTILIZER SOWER WITH HOE TO WORK FERTILIZER INTO SURFACE SOIL.

ble portions of both nitrogen and phosphoric acid contribute to the immediate needs of the plant, and the less soluble to its continuous and steady growth, and to the potential fertility of the soil.

The different kinds of vegetables.

As previously stated, distinctions should be made in reference to the kinds and amounts of plant-food applied to the many different vegetables. It is impossible in a discussion of this nature to give specific directions of the details of fertilization of each vegetable; hence, the dis-

cussion following will give consideration to the various groups of edible plants as outlined by L. H. Bailey, and as much detail concerning each plant as is practicable. This grouping is an excellent one because it is based upon the object of growth, which is an important factor in the cultural methods and fertilization of the various vegetables.

ROOT CROPS

Beets and turnips.

The early table beet and the early turnip are very important market-garden crops. Wherever grown, whether in the South for the northern market, or in the middle states for the near-by market, earliness is a primary consideration; and the earliness of the crop is determined largely by the amount and availability of the nitrogen and phosphoric acid applied. These are the two elements which, more than any others, modify and dominate the growth of these plants, and contribute to their profitable production as early market-garden crops. In the case of early turnips particularly, a difference of two or three days in the beginning of the harvest will often determine the profit or loss upon the crop. The experience of many growers confirms the view that for no other crop is the necessity for right fertilization more important. Since the early growth of these crops takes place before active nitrification begins in the soil, dependence for this element must be placed upon the nitrogen applied, and it is desirable not only that the soils should be well supplied at the time of planting with all of the constituents, but that frequent top-dressings of the soluble nitrate shall be made. Top-dressings are recommended because the application of a sufficient amount of the nitrogen in this form at the

time of seeding might result in its considerable loss, since at this season rains often occur which are frequently so heavy as to cause a leaching of the nitrates into the drains or into the lower layers, and thus prevent the continuous feeding of the plant, and a consequent delay in growth.

An application, therefore, of from 1000 to 1500 pounds of a high-grade fertilizer, one of the composition of the basic fertilizer already suggested (p. 287), is frequently employed at the time of seeding, followed by a top-dressing of from 50 to 100 pounds of nitrate of soda to the acre once every week or ten days, for at least three or four weeks after the plants have well started. It will meet the requirements for added fertility. Such a practice, under average seasonal conditions, insures a continuous and rapid growth, and obviates to some extent the dangers liable to follow from too much rain or from drought. The frequent applications prevent losses from leaching if heavy rains follow, and, except in case of excessive and prolonged drought, the nitrate remains in solution, and is ready to be immediately absorbed by the plant. The advantage of earliness which is gained by the use of apparently excessive amounts of nitrogen is twofold: a higher price is received for the product, and the cost of labor required for each unit of income is less. Quite as large yields may be obtained by smaller dressings, but the net income is reduced as the time necessary for the growth of a marketable beet or turnip is increased. See also Chapter XIV, in reference to this subject.

Carrots.

The food requirements of carrots are very great, a yield of 15 tons an acre will remove 48 pounds of nitrogen, 27 of phosphoric acid and 153 of potash. For high-grade

edible carrots, no less than 1000 pounds of a mixture carrying 4 per cent of nitrogen, 4 per cent of phosphoric acid and 12 per cent of potash should be used. In case the season is favorable for rapid development, top-dressings of nitrate of soda are very profitable.

The other crops of this group, including celeriac, chicory, horseradish, parsnip, radish and salsify, may be fertilized with liberal applications of the basic fertilizer. It should be remembered in connection with each that the crops of this group require large quantities of potash, and that phosphoric acid is relatively much less important.

BULB CROPS

This group includes chive, garlic, leek, shallot and onion. Because the onion is the most important it is discussed liberally. The fertilization of the other crops may be the same.

The growing of onions, either from seed or from sets, and the growing of sets according to "intensive" systems of practice, requires a soil of a suitable physical character well supplied with all of the essential constituents of fertility. The minerals should be supplied in abundance by superphosphates and potash salts, while the nitrogen should be supplied in the most active forms, and in even larger amounts than for many other crops. The present systems of growing these crops require that the sets shall be planted and the seed sown more thickly than was formerly believed to be desirable, which permits of a larger yield to the unit of area, though it requires better culture and a very much larger quantity of available plant-food than was the case under the former rather "extensive" systems of culture. Except in the case of very

early onion crops, immediate rapid growth after setting is not so essential as in the case of many other market-garden crops, and in the growing of onion sets, when the soil is richly provided with food, great care in management is necessary in order to secure a development of bulb that shall not be too large, in which case the salable quality of sets will be reduced. Hence, to avoid this, the seed should be spread thickly, in rows about 3 inches wide, and the cultivable portion between the rows about 8 inches wide. With so large a portion of the surface area occupied with the crop, the danger of too large development from heavy fertilization is greatly reduced.

In growing scallions, the soil should not only be richly provided with minerals and organic forms of nitrogen, as in the case of the other, but should be supplied early with soluble nitrate, in order to meet the demands for this element before it is available from soil sources. In the growing of crops which require so much hand labor as onions, fertilizers are also preferable to yard manures, because they are free from weed seed. Further, fertilizers do not contribute toward the development of insects or diseases, as is sometimes the case with manures, particularly with the product derived from city stables.

A good general fertilizer for onion sets for soils of fair fertility may consist of about 50 pounds to the acre of nitrogen in organic forms, as dried blood, cotton-seed meal or tankage, 60 of phosphoric acid, which may be partly in organic forms, as bone or tankage, and 100 of actual potash, derived from a muriate. The application of a formula containing —

Nitrogen	5%
Phosphoric acid	6%
Potash	10%

at the rate of 1000 pounds to the acre, and well worked into the soil previous to planting, would furnish these amounts, and this application, together with a top-dressing of from 75 to 100 pounds to the acre of nitrate of soda, or 60 to 75 pounds of sulfate of ammonia, two or three times at intervals of about three weeks, the first after the crops have well started, would provide not only an abundance of food of the right sort, but the nitrogen when needed, without danger of loss.

If the soil has been well dressed with a general fertilizer, as above described, the scallions should receive a dressing of nitrate just as soon as growth begins in the spring, as rapid and early growth at this season will, other conditions being equal, depend upon the supply of available nitrogen, and nitrogen in available forms is not usually present in the soil in sufficient quantities so early in the season.

COLE CROPS

Broccoli, brussel sprouts, cabbage (see Fig. 28, Plate XIV), collard, cauliflower and kale are all large-leaved plants and voracious feeders, and are specifically benefited by large applications of nitrogen and of phosphoric acid. Heavy applications of the basic fertilizer, which is excellent, should be supplemented upon good soils with additions of nitrogen and phosphoric acid, and upon light soils, potash may also be added. Notwithstanding the fact that these crops are particularly benefited by nitrogen, the character of the edible portion or head of the different plants is very largely influenced by the nature of the growth. Too rapid an early growth, due to an excess of nitrogen, frequently results in an abnormal development of leaf, which is not accompanied by a

proper formation of the head; hence a part of the nitrogen essential for the growth of the plant after the head has begun to form should be applied at this time in an immediately available form, and a part in forms which will gradually feed the plant. A good method of fertilization, in addition to the application of from 1000 to 1500 pounds to the acre of the basic fertilizer, therefore, may consist of a top-dressing of 100 pounds of nitrate of soda and 200 of superphosphate to the acre, after the plants have begun to make growth after transplanting. After the heads begin to form, another top-dressing of 200 pounds of nitrate of soda may be applied, which will contribute toward a rapid and continuous growth of head, provided an abundance of the minerals is present, as already indicated.

A number of crops belonging to this group of plants require, in addition to a sufficient supply of plant-food, peculiar climatic conditions for their best crop development. Cauliflower, particularly, not only seems to be so influenced, but great skill and experience are required on the part of the grower. It must be remembered that while proper fertilization is essential, it is only one of the primary conditions of successful culture.

POT HERBS

Beet, chard, dandelion, mustard, sea kale and spinach, grown for their tops or the edible portion of the leaf, are encouraged in their development by an abundance of available nitrogen, as this element is the one which contributes more than any other to formation of leaf. Abundant growth of the right sort is only accomplished when it is present in such quantities and in such forms as to con-

PLATE XIV. — Cabbage and Watermelons.

Fig. 28. — Cabbage Heavily Fertilized, Freehold, New Jersey.

Fig. 29. — Watermelons, Peppers and Corn Fertilized with Basic Fertilizer, Clarksboro, New Jersey.

tinuously supply the plant with its needs. Reasonably heavy dressings of the basic formula, 1000 pounds to the acre, or over, at time of planting, should be followed by a top-dressing of 100 pounds to the acre of nitrate of soda after the plants are well started. The late fall and winter growth of spinach is especially benefited by the application of nitrates.

SALAD CROPS

Celery.

Celery is another plant that luxuriates in a soil rich in vegetable matter, though the peculiar advantage of this natural condition of soil may be largely met where it is possible to secure an abundance of water and plant-food in soluble forms. In the absence of an abundance of water, even the best judgment in application of fertilizers will not result in satisfactory growth. A heavy application of the basic mixture — a ton to the acre, used at time of setting the plants — may be followed with advantage by frequent and reasonably heavy top-dressings of nitrate of soda, 100 pounds to the acre or more, and well worked into the soil. This abundance of soluble nitrogen will contribute toward that rapidity of growth which is accompanied by the peculiar crispness and sweetness that gives edible quality to this vegetable. In the absence of sufficient water and food, not only is the growth of the plant retarded, but the quality of that obtained is materially influenced, since the development of the bitter flavor and fibrous character that frequently cause a reduced consumption of this valuable plant is apparently encouraged.

What has already been said concerning this vegetable is true of a number of others: the main thing is to see to it that such an abundance of available food of the right

kind is provided as to make possible a rapid growth when other conditions are favorable. This is one of the primary necessities, if a high yield of good quality product is obtained.

Lettuce.

There is no market-garden crop which derives greater benefit from heavy applications of stable manure than lettuce. Besides increasing the amount of plant-food in the soil, it helps to bring about that mechanical condition of soil so important in successful lettuce-production. Crispness and high quality are essential to make lettuce readily marketable, hence an abundance of all the constituents of plant-food in available form must be present in the soil. An application of no less than 1000 pounds of the basic mixture should be used at the time of planting, supplemented with dressings of nitrate of soda at the rate 100 to 150 pounds to the acre at intervals of ten to fifteen days after the plants are of fair size.

The fertilization of corn salad, cress, endive and parsley, the other plants of this group, may be essentially the same as that suggested for lettuce. They are all grown for the leaves and require fertile soils liberally supplied with all the constituents of plant-food in available forms.

PULSE CROPS

Peas and beans of the various kinds and varieties belong to the legume family, and possess the power of acquiring nitrogen from the air; they are, therefore, ordinarily placed in a separate class in respect to their fertilization with nitrogen. When they are grown as market-garden crops, however, it is frequently the wiser economy

to apply nitrogen, particularly if they are raised upon land which has not been previously planted with these crops, and thus may not possess the specific nitrogen-gathering bacteria: because it is imperative that the plants should not only have an abundance of all of the food constituents, but that their food should be such as to cause as long a cropping period as possible, and nitrogen will contribute to this end. Hence, in the fertilization of these crops, while the minerals are the primary constituents needed, nitrogen should also be applied, and it should preferably be in the organic forms, which encourage a longer period of growth, rather than in the single, active-form nitrate, more generally recommended for the quick-growing market-garden crops, because its complete solubility and immediate availability encourage a rapid growth and short period of development. The basic fertilizer recommended, if applied at the rate of 500 to 600 pounds to the acre, will usually furnish sufficient nitrogen, and may, if necessary, be supplemented by the application of amounts of superphosphate and potash salts which will add from 20 to 30 pounds of phosphoric acid, and 60 to 75 of potash.

SOLANACEOUS CROPS

Eggplant.

The eggplant belongs to the same botanical family as the potato, and while specifically benefited by the fertilizers recommended for that crop, is improved by the further addition of nitrogen, which stimulates an early leaf growth. Good organic forms are quite as useful as the nitrates or ammonia, unless the latter are used frequently as top-dressings. (See page 239.)

Peppers. (See Fig. 29, Plate XIV.)

The same treatment may be accorded peppers when grown under garden conditions as previously suggested on page 257, except that a more liberal supply of plant-food may be made. It should be remembered, especially in connection with liberal applications of stable manure, that an abundant supply of minerals should be present in the soil to encourage continuous growth and fruiting. After the plants are well established, an abundance of available nitrogen should be avoided.

Tomatoes.

The fertilization of both early and late tomatoes is discussed in Chapter XIII, and it seems unnecessary to add to that discussion here except to emphasize the importance of a liberal supply of the mineral elements — phosphoric acid and potash. Many growers have found the Wagner system of fertilization, which is based upon the necessity of an abundant supply of minerals and fractional applications of available nitrogen, a good practice. (For Wagner System, see page 205.) On the other hand, there are many growers who prefer to make a single application in large amount of a fertilizer deriving its nitrogen from a number of sources. A mixture very generally used in New Jersey is made of the following materials:

Nitrate of soda	100 lb.
Sulfate of ammonia	100 lb.
Dried blood, 16% AM.	100 lb.
Ground fish	100 lb.
Ground bone	100 lb.
Acid phosphate.	1100 lb.
Sulfate of potash	400 lb.

This is undoubtedly an excellent mixture which may be used with safety in almost any quantity. The usual practice is to use from 1000 to 1200 pounds to the acre. Many farmers claim that the sulfate of ammonia causes some injury to the tomato and prefer to double the quantities of blood and fish used. Whether there is any ground for this claim has never been definitely determined, but it is known that sulfate of ammonia leaves a large residue of acid in the soil.

VINE CROPS

Cucumbers, watermelons (see Fig. 29, Plate XIV), muskmelons, pumpkins and squashes belong to one botanical group of plants, and are usually adapted for similar climatic and soil conditions, though watermelons and muskmelons of good quality are successfully grown only upon light, warm, sandy soils. The pumpkins, cucumbers and squashes may be readily grown to perfection upon the colder and more compact clayey soils. All of these crops require an abundance of vegetable matter in the soil, in order to make their best growth. Hence, upon soils deficient in this respect, manures should be applied which are rich in vegetable matter. Composts in the hill have proved of especial advantage, as they seem to encourage an immediate feeding, and prevent delay in early growth. In the best growth of these plants it is also necessary that the mineral elements shall be available, and that the nitrogen shall be of such a character as to encourage a continuous rather than a quick growth of vine. That is, unless the quick-acting nitrates are applied very frequently, they are less desirable than organic forms of nitrogen. Hence, with the

usual broadcast application of the basic mixture at the time of planting, together with a compost in the hill, further applications of organic nitrogen should be made, its character to be such as to promise a relatively rapid change into nitrate. The basic mixture may be reënforced by any one of the following materials: 200 to 300 pounds to the acre of cotton-seed meal, 100 to 200 of dried blood or 300 to 400 pounds of fine-ground tankage or ground fish. Any organic substance whose greater part will decay in one season will generally give better results than the nitrate, unless the latter is applied in frequent small top-dressings, because organic forms of nitrogen provide for a continuous growth of vine and fruit, while too great an abundance of immediately available nitrogen as nitrate is liable to cause too rapid and large growth of fruit of poor quality. This does not apply in the case of cucumbers for pickling, where a large setting of immature fruits is desired. In this case, nitrogen in the form of a nitrate, if properly applied, will contribute to a large setting and a rapid growth of the fruits.

MISCELLANEOUS CROPS

Asparagus.

Asparagus is one of the very important vegetable crops, and perhaps no other renders so profitable a return for proper manuring and fertilizing. It differs from the majority of the others in two essential particulars. First, it is a perennial, the length of life of a bed depending largely upon the treatment; and second, only one crop can be obtained in a season — it occupies the land to the exclusion of other crops. Hence, special efforts should be made to obtain as large a crop as the conditions of season

and climate will permit. With this plant the yield and market quality of the crops depend upon the number and size of the shoots. In respect to quality, the demands of the different markets vary. Some of them require that the shoots shall be bleached and so cut as to present only a green tip, the remainder being perfectly white, while others demand that the shoot shall be green. But in both cases, the size of the shoot determines salability, and the size is largely measured by the methods observed in feeding the plant when other conditions are favorable; that is, if not injured by disease or insects. Small, spindling shoots usually indicate that the crop has not been well cared for, or that the plant has been imperfectly nourished.

The root is enlarged and invigorated by the character of the growth of the tops, or summer growth of the plant after cutting is finished, and it is obvious that the manuring should be such as to encourage not only a rapid growth of shoots early, but a large and vigorous growth of tops later, which assists the growth of the roots in which energy is stored up for the production of the crop in the following year. Hence, not only the character but the method of fertilization is important, and it differs from that recommended for those plants which grow from the seed in one season and which must depend upon what they are able to acquire during their short period of growth.

It was formerly believed that one of the most important ingredients of manures for the asparagus plant was common salt, and that in any fertilization this substance should occupy a prominent part. Experience has shown, however, that while salt may not be harmful, there is no real fertility value in it. The crop may be profitably grown without its application, though it does no harm, and there is no objection to its use except on the ground

that it adds no essential fertility element, and its indirect benefit may be obtained more cheaply by the use of other materials, which contain salt as a normal ingredient, — for example, kainit, the crude potash salt, which is one-third salt, though its market price is based solely upon its potash content.

Fertilizers which have been found very useful for asparagus are those which contain food both in immediately available and in gradually available forms. During the early growing season, the available food may be appropriated rapidly enough to cause an increase in the yield of shoots of that year; and inasmuch as the plant continues to grow until winter, the food that becomes gradually available is appropriated later, and contributes to the strength and vigor of the roots upon which the next year's crop depends. Furthermore, because the crop is gathered from the early shoots, which are continuously removed for from one to two months, the root is continuously drained of its stored-up material, and at the end of the cutting season it has been very much reduced in vitality; wherefore it is particularly desirable that available food be applied at this time also, in order to encourage a rapid and vigorous growth of the top, which aids in the storing up of food in the root. A fertilizer containing —

Nitrogen	4%
Phosphoric acid	8%
Potash	10%

the nitrogen to be drawn from both soluble and organic sources, and the phosphoric acid from both superphosphate and ground bone, or tankage, and the potash from muriate, may be applied at the rate of 1000 to 1500 pounds to the acre, and thoroughly worked into the soil at the time of

setting the crowns, or even in greater amounts from year to year, preferably early in the spring, in order that the plant may have the whole season for the appropriation of the food.

The specific fertilizer, in addition, should contain immediately available forms of food, and should be applied preferably immediately after or during the latter period of the cutting, in order to feed at once, and thus stimulate and strengthen the plant in its condition of lowered vitality, due to the continuous and large removal of the shoots. This application should also be liberal, since, as already indicated, limitations at this time may result in a greatly decreased yield and a poorer quality of product the next year, and hence a reduction in profit. The best growers apply, in addition to the fertilizer recommended, and after cutting, not less than 250 pounds of nitrate of soda, 300 of superphosphate, and muriate of potash, or kainit, equivalent to 100 pounds of actual potash.

These recommendations as to the amounts of fertilizers may seem rather large to those who have been accustomed to light applications, but they are the minimum rather than the maximum amounts, as many growers have learned that the extra amounts applied are preferable to the smaller amounts, contributing not only to the length of life of the plant, but also to the total yield and size of the shoots, as well as to their edible quality, which is measured by their succulence and flavor.

These suggestions as to fertilizers are for conditions where large amounts of organic or natural manures are not readily obtainable. When these are used, they may serve instead of the basic fertilizer, but cannot well substitute the special applications of artificial fertilizers made after cutting is finished.

The fertilization suggested above may be used with absolute safety and excellent results may be obtained, but it should be kept in mind that investigators and growers differ greatly regarding the fertilizing of asparagus. While it is conceded that nitrogen is the most important element, the form and time of application are still matters of contention. As an alternative method, Watts makes the following suggestions: "If seeds and plants have been selected intelligently and all cultural conditions are favorable, the following treatment should give good results: Apply 10 to 15 tons of fine manure early in spring, or probably with as much benefit immediately after the cutting season; one and one-half tons of a 4–8–10 mixture, half applied in early spring, and half immediately after the first cutting; 150 pounds of nitrate of soda by broadcasting as soon as growth begins in the spring; 150 pounds of nitrate of soda when the cutting season is half over; 150 pounds of nitrate of soda at the close of the cutting season and the same quantity one month later."

Rhubarb.

Rhubarb is a crop somewhat similar to asparagus, in that it is a perennial, and that the best fertilization is one which not only provides food for the growth of the immediate crop, but which encourages the growth of top after the regular crop is harvested, and thus restores the vitality of the plant — which has been weakened by the continuous removal of the stalk and leaf — and enables it to store up energy for the subsequent crop. An annual application of 1500 pounds of the basic formula (p. 287) early in the spring, preferably plowed in, may be followed with advantage by a top-dressing of 150 pounds to the acre of nitrate of soda in about two weeks after harvesting

has begun, and a similar dressing after harvesting has ceased. These dressings should be cultivated into the soil, unless immediately followed by rain, which will distribute the salt into the lower layers of soil. Plants of this sort, from which only one crop can be secured, should be stimulated to the largest possible production.

Sweet corn.

In the case of sweet corn, the early crop is usually the most profitable. The recommendations that are made for the fertilization of the field crop do not apply to this, because the object is not the matured crop, which makes its greatest development in July and August, the most favorable season of growth, but the early green product, which is often harvested before the field crop has fairly begun to grow. This early and rapid growth, therefore, cannot be attained by methods of fertilization suitable for the field crop (Chapters XII and XIV). It can be accomplished only when an abundance of the mineral foods is present, and when the nitrogen is in part, at least, in forms which may be directly absorbed, as much growth must be made previous to the time that nitrification takes place in the soil.

The large quantity of well-rotted manure which, until recently, was practically the only manure used for this crop, while extremely valuable, can be in part substituted by a liberal dressing of the minerals, phosphoric acid and potash, and further supplemented by nitrogen in readily available forms. The use of 1000 to 1200 pounds of a mixture composed of the following ingredients

Nitrate of soda	200 lb.
Dried blood, 16% AM.	100 lb.
Ground fish	200 lb.
Acid phosphate	1200 lb.
Muriate of potash	300 lb.

may be practiced with advantage. Where cotton-seed meal may be secured at a reasonable price, it may be used instead of fish. This mixture should be supplemented by top-dressings of nitrate of soda whenever the plants show that more nitrogen is needed. Care should be taken to work the nitrate of soda into the soil immediately after the application is made. The basic formula (page 287) used at the rate of 800 to 1000 pounds to the acre and supplemented by top-dressings of nitrate of soda may be used with good results if more convenient.

Okra.

The production of okra is increasing, especially in the canning sections, where it is grown extensively and the pods prepared for soup. It requires a warm and fertile soil. Because okra is grown for pods while still green and which must be crisp and tender, an early and vigorous growth of leaf and stem is required. The best practice is to use no less than 1000 pounds of a high-grade mixture deriving a large part of its nitrogen from nitrate of soda, and the remainder from quickly available forms, as blood, fish, cotton-seed meal and tankage. Because it continues its growth late in fall, tankage, which is less available than the other materials, is valuable. The minerals should be present in the soil in abundance. Stable manure is desirable because it improves the mechanical texture of the soil, as well as to supply plant-food.

CONDIMENTAL OR SWEET HERBS

There is a large number of sweet herbs common to European gardeners but of little commercial importance in this country. It is not uncommon, however, to find

one or more of these plants in most any American garden. The fertilization of these crops, including dill, mint, sage, savory, thyme and tansy, is in large degree dependent upon the object of their use, that is, whether for leaf or seed. In general, they require a warm soil well supplied with all the elements of plant-food. A liberal application of manure and 1000 pounds of the basic fertilizer should be sufficient.

In all of the suggestions made as to the fertilization of market-garden crops, not only has the question of yield been kept in mind, but also the quality of the product, which is a measure of salability. The question is often raised as to whether the forcing of these crops by means of active fertilizers may not result in too coarse and one-sided a growth. Such growth does frequently follow a heavy fertilization with nitrogen, if accompanied by too light a fertilization with minerals. The tendency of the plant is to make a normal development when a sufficiency of all of the fertility elements are present, but in these crops the object is really a one-sided growth in many cases, since that growth is usually better adapted for the purpose than that obtained under what may be regarded as normal conditions. It must be remembered, too, in the growing of certain vegetables, such as radishes, celery, etc., or those in which the roots are the edible portion, that commercial fertilizers do not contribute any undesirable flavors. In fact, they are often largely responsible for those peculiar characteristics which give quality; whereas, when these vegetables are grown by the exclusive and necessarily excessive applications — if large yields are to be secured — of natural manures, undesirable qualities are frequently contributed by them.

CHAPTER XVI

ORCHARD FRUITS AND BERRIES

It is not until within recent years that the question of manuring or fertilizing fruit trees and berries has come to be of particular interest. This is due primarily to the fact that demands for fruit and berries have been relatively limited as compared with the staple crops. Hence, fruit-growing as a business, or on a commercial scale, is comparatively new, though the opinion is quite prevalent among fruit-growers that trees, particularly, are indigenous to most soils, and grow freely like weeds, and that therefore orchard crops are not as exhaustive of the fertility elements as others. They cite, as an argument on this point, the fact that lands from which timber has been recently removed are much more productive than those upon which many regular farm crops have been grown. Scientific investigation and practical experience, however, teach that forest growth and fruit growth are quite different in respect to the needs of fertilizing elements, and that progressive fruit-culture demands that quite as much attention shall be given to the matter of providing proper plant-food as is now known to be desirable for the other and more common crops of the farm grown for profit.

FRUIT CROPS DIFFER FROM GENERAL FARM CROPS

It is obvious that suggestions as to the character of the fertilizing of the cereal crops, grasses and vegetables, must be somewhat different from these fruits, because the

former differ from the latter not only in their habits of growth, but in the character and composition of the crop produced, and in their relation to soil exhaustion. General farm crops, with few exceptions, require but one year for the entire processes of vegetation and maturation. Fruit crops, as a rule, require a preparatory period of growth of tree or bush before any crop is produced, which is longer or shorter according to the kind of fruit. Furthermore, after the fruit-bearing period begins, the vegetative processes do not cease, but are coincident with the growth and ripening of the fruit. The crop product, or the fruit, also differs materially in its character from the general farm crop, or from vegetables, which reach their harvesting stage and die in one season, because for many kinds a whole season is required for growth and development.

That is, in fruit-growing it is necessary that there shall be a constant transfer of the nutritive juices from the tree to the fruit throughout the entire growing season, while the growth for each succeeding year of both tree and fruit is dependent upon the nutrition stored up in buds and branches, as well as upon that which may be derived directly from the soil.

"In the next place, the relation of fruit-growing to soil exhaustion is very different from that in general-crop farming, because in orchards there is an annual demand for specific kinds and definite proportions of soil constituents. It is really a continuous cropping of the same kind, and there is no opportunity, as in the case of ordinary farm crops, to correct the tendency to exhaustion by a frequent change of crops, or the frequent growth of those which require different kinds and amounts of plant-food constituents." [1]

[1] Voorhees, "Manuring Orchards." Lecture before Massachusetts Horticultural Society, 1896.

THE SPECIFIC FUNCTIONS OF THE ESSENTIAL FERTILIZING CONSTITUENTS

It must be admitted, however, that the general principles of manuring, as applied to farm crops, also apply to fruit and berry crops; that is, the essential manurial constituents must be the same.

"A fruit tree will not make normal growth in a soil destitute of nitrogen. That nitrogen encourages leaf growth is a recognized fact, and since trees grow by means of both leaf and root, its presence is required in the soil in order to promote the growth and extend the life of the tree. It is very evident, too, that potash is an essential constituent in the growth of fruits, not only because it constitutes a large proportion of the ash of the wood of the apple, pear, cheery and plum, and more than 50 per cent of the ash of fruit, but because it forms the base of the well-known fruit acids. Phosphoric acid is also very essential in order to nourish a tree properly, as well as to insure proper ripening, though it is apparent from such investigations as have been made that this constituent is relatively of less importance than for the cereals."

It is also a matter of common observation that in the production of stone-fruits, particularly, lime is an important constituent. Its functions seem to be to strengthen the stems and woody portion of the tree, to shorten the period of growth, and to hasten the time of ripening. Fruit trees growing on soils rich in lime show a stocky, steady, vigorous growth, and the fruit ripens well, while those on soils which contain but little lime, particularly the clays, appear to have an extended period of growth, the result of which is that the wood does not mature and the fruit does not ripen properly.

THE CHARACTER OF SOIL AN IMPORTANT CONSIDERATION

Soils which possess good mechanical condition, are rich in the essential constituents, — nitrogen, phosphoric acid and potash, — contain a good proportion of lime and are well drained and cultivated, are naturally well adapted for fruit trees, as well as for other crops, and the exhaustion of such soils will not become apparent for a long time. But soils of this character are the exception rather than the rule, and the growth of fruit on those which possess the opposite characteristics cannot be continued for any considerable period without an artificial supply of the fertility elements. In fact, it is doubtful whether it ever pays to attempt to grow fruits on soils of the latter character without supplying them with an abundance of the essential fertilizer elements.

In the matter of berries, which are crops especially well adapted to soils which possess a light, open character, but which are not naturally supplied with the essential plant-food constituents, proper manuring becomes of even more importance than for the tree fruits; though, because of their shorter period of life, one or two good crops may be secured without heavy fertilization.

On the whole, however, for all of these crops the great need at the present time is for a larger use of fertilizing materials, not only because a larger yield may be obtained thereby, but because the quality of the product is far superior to that grown under conditions which are not perfect in this respect. Quality, which is determined by size and appearance, is, other things being equal, largely dependent upon an abundant supply of plant-food. It is manifestly impossible to include all fruit and berry crops in one general group, though possessing points of resemblance, because

the different ones vary more or less in their character. The trees of certain of them are long-lived, — 40 years or more, — while others are comparatively short-lived — 10 years or less. In certain of them the cropping period is short; the fruit ripens at once, while in others the ripening period extends over a considerable time. They also differ in reference to their demands for plant-food, certain of them requiring an abundance of available food, while others can readily absorb the food necessary for their growth from relatively insoluble compounds. In the discussion, similar recommendations may be made in many cases, though it is desirable that each class of fruits shall be considered separately, and also that distinctions should be made between what are regarded as good soils, as medium soils and as poor soils, in respect to their content of plant-food.

THE GENERAL CHARACTER OF THE FERTILIZING

It must be borne in mind, also, that inasmuch as the fruit crop is not derived from annual plants, but from perennials, the character of the feeding may be very different from that in which the entire plant serves as a crop, as is the case with the cereals and most vegetables. Hence, the fertilizers applied need not all be of such a character as to be immediately available. That is, the fertilizing materials may be such as to provide for a gradual and continuous feeding. Those forms which decay relatively slowly are, perhaps, quite as good, if not better, for many kinds of fruits than those which by virtue of their solubility and immediate availability are more stimulative in their character. Those fertilizers which do not contribute to the immediate feeding of the tree or plant, but rather add to

the reserves of potential plant-food in the soil, should, however, in many cases be supplemented by those which act more quickly, in order to supply an abundance of available food at special times and seasons. In general, therefore, a basic formula, the chief claim of which is that it furnishes large percentages rather than specific proportions or forms of plant-food, may be more reasonably adopted for fruits and berries than for other crops, because it may be applied with advantage to all of the fruits, the amounts to be applied to be adjusted to meet the requirements of the different kinds of crop and the different kinds of soil. Fertilizers which have been found to be very serviceable for fruit crops have been made according to the following formulas, the materials of which are familiar to all, and may be readily obtained from dealers: (1) One part, or 100 pounds each, of ground bone, acid phosphate and muriate of potash; or (2) a mixture of one and one-half parts, or 150 pounds, of ground bone, and one part, or 100 pounds, of muriate of potash; the mixture of either to be applied in all cases. For fruit trees on soils of good natural character, further additions of more active forms of the various constituents may not be needed, while on light soils, or those of a medium character, or for berries, they should be added.

The chief point to observe is that an excess of nitrogen must be avoided, and that if this element is applied in active forms, it should be used at such times as to enable the plant to appropriate it early in the season, and thus become assimilated before the beginning of winter, the danger from too great an excess of nitrogenous fertilizers being that it causes a too rapid growth of both wood and fruit, which do not ripen well.

THE APPLICATION OF FERTILIZERS FOR FRUITS

A point which should be carefully observed in the fertilizing of orchards is the method of application. The fertilizers should, as far as possible, be distributed throughout the lower layers of soil, where the feeding roots are located. If applied wholly on the surface of the soil, the tendency of the root is to go to that point, or where the food is, and trees which have the larger proportion of the feeding roots near the surface are more liable to suffer from drought than those which have them distributed at greater depths in the soil. Hence, in the application of fertilizers to orchards, particularly in the early life of the trees, they should, as far as possible, be well worked into the soil, which may be readily accomplished by applying upon the surface before plowing. The after-fertilizing, if it seems desirable to leave the orchard in sod, may be upon the surface, though in that case the soluble fertilizers are preferable, since they would rapidly descend, while the insoluble would do so more slowly, or only as rapidly as they became soluble.

THE FERTILIZING OF APPLES AND PEARS

The necessity for the application of fertilizers in the growing of apples and pears is largely due to the fact that it is really a continuous cropping of the same kind, and therefore more exhaustive than a cropping which removes more plant-food in the same period of time. While upon good soils the trees may be able to acquire sufficient food to mature maximum crops for a considerable period, the life of the tree, as well as the character of the fruitage, will be very favorably influenced by the fertilization.

An experiment [1] bearing upon this point is very instructive, as indicating the need of manures for fruit trees, not only in reference to the amount removed, but also in reference to the proportions of the essential constituents required. This study shows that the plant-food contained in 20 crops of apples, of 15 bushels to the tree, and 35 trees to the acre, and in the leaves for the same period, amounts, in round numbers, to 1337 pounds of nitrogen, 310 of phosphoric acid and 1895 of potash. These amounts of plant-food are compared with the amounts that would be removed by 20 years' continuous cropping with wheat, assuming an average yield of 15 bushels of wheat to the acre, and 7 pounds of straw to 3 bushels of grain; viz., 660 pounds of nitrogen, 211 of phosphoric acid and 324 of potash. By this comparison it is shown that the 20 crops of apples remove more than twice as much nitrogen, half as much again of phosphoric acid and nearly three times as much potash as the 20 crops of wheat.

These results are valuable in indicating the rate of soil exhaustion by apple-growing. It is to be remembered, however, that the larger root development of the tree would enable it to draw its nourishment from a larger area of soil than is the case with wheat, and thus probably permit of normal growth for a longer period.

Too many are satisfied with short crops of medium fruit, with off-years and with short-lived trees, largely because they do not know that all of these conditions may be improved by a proper feeding of the tree, and that such feeding will usually result in a very largely increased profit.

Statistics gathered in the state of New Jersey [2] show that

[1] Cornell Exp. Sta., Bulletin No. 103, "Soil Depletion in Respect to the Care of Fruit Trees."

[2] Bulletin No. 119, New Jersey Experiment Station.

over 90 per cent of the commercial apple-growers in the southern and central sections use fertilizers or manures for their orchards, whereas, in the northern section about 70 per cent use manures. In the northern section the orchards are usually located upon soils of a very high natural strength, and which are peculiarly well adapted for the growing of fruits, while in the central and southern sections, the soils in many sections are of medium, if not of very low, fertility. Hence, while the larger proportion of the growers use fertilizers or manures upon the poor soils, a very considerable number use manures for orchards located upon soils which are regarded as of the best; yet all claim that it is a paying practice.

There is also a difference in the time at which manuring or fertilizing should begin. When the soil is naturally good the fertilization need not begin with the setting of the tree, as the food obtainable is usually sufficient to provide for a good growth of leaf and wood, and in many cases maximum crops of fruit for a number of years, though even here fertilization should preferably begin as soon as large crops are produced, whereas, on the lighter soils, fertilization should begin when the tree is set.

The amounts to be applied.

For these crops, either of the basic mixtures suggested (p. 313) will provide a sufficient proportion of nitrogen, except possibly upon the more sandy soil. On light soils, the necessity for liberal fertilization with nitrogen is frequently apparent. In many cases it is possible to obtain the necessary nitrogen from the growing of leguminous crops, as crimson clover, though when these are used they should be plowed down early in the spring, in order that their growth may not interfere with the growth of the tree.

If they are allowed to remain until mature, they absorb not only the food that may be necessary for the growth of tree and fruit, but the moisture also, and thus they frequently injure rather than improve the crop prospects.

On soils of good natural character, the fertilization of apples and pears should begin as soon as the trees reach the bearing period, and an annual application of 400 pounds to the acre of either formula should be made, preferably in early spring, and plowed in. As they grow older and the yield of fruit is larger, the amounts should be increased. While no definite rules can be laid down as to the most profitable amounts to apply, the best growers find that it pays to use from 1000 to 1500 pounds annually of mixtures which furnish practically the amounts and kinds of plant-food contained in the formulas suggested. The profit is found, not only in the larger yield, but in the quality of the fruit and in the increased tendency toward continuous crops, and in longer life of the tree. On soils of medium character the fertilization should begin earlier, and the amounts of the basic fertilizer should be larger. In many cases, too, nitrogen, in addition to that contained in the basic formula, should be added, the kind and form depending, perhaps, upon the relative cost more than upon any other one thing, the minimum amount to be 20 pounds to the acre, or an equivalent of 125 pounds of nitrate of soda.

On poor soils, the necessity for fertilizing is naturally greater than for either of the others. In fact, on these liberal fertilization — 500 pounds to the acre of basic formula No. 2 — should precede the setting of the trees, and be continued annually. On these soils, too, green manuring as a source of nitrogen can be practiced with safety for a longer period than in the preceding case. In

the presence of an abundance of minerals, the need for nitrogen is indicated by the color of the foliage. If it lacks vigor and is yellow in the spring, rather than green, a dressing of from 100 to 150 pounds of nitrate of soda will supply the needs to better advantage than any other form.

PEACHES

Peaches differ from apples and pears in respect to fertilizing because the period of development of the tree, preparatory to bearing, is shorter, and because the cropping is usually much more exhaustive. Hence, the demands for added plant-food are proportionately greater in the early life of the tree, and are different, because of their more rapid growth. That is, forms of nitrogen that are more available are preferred to the slowly available materials recommended for apples and pears.

The need of fertilizers.

The results of an experiment conducted by the New Jersey Experiment Station are interesting and valuable, as bearing upon this point. They show the value of fertilization, not only in increasing the yield of crops, but in extending the period of life of the trees, and in overcoming unfavorable crop conditions. The soil upon which the experiment was conducted possessed only medium fertility, good mechanical condition, and was fairly representative of soils naturally well adapted for peach-growing. The fertilized plots received annually —

Nitrate of soda	150 lb.
Bone-black superphosphate	350 lb.
Muriate of potash	150 lb.

PLATE XV. — Fertilizers for Peaches.

FIGS. 30 and 31. — VIEWS OF THE VINELAND EXPERIMENTAL PEACH ORCHARD, NEW JERSEY EXPERIMENT STATION, SHOWING (FIG. 30) EFFECT OF NITROGEN IN ADDITION TO MINERALS; FIG. 31, BELOW, MINERALS ONLY, NO NITROGEN.

to the acre, whereas the manured plot received manure at the rate of 20 tons to the acre.

The following tabular statement shows the results obtained:

I. THE YIELD WITHOUT MANURE

	Baskets to the acre
1884–1891, inclusive, 8 years, average per year	65.7
1884–1895, inclusive, 10 years, average per year	60.3
1887–1891, inclusive, 5 crop years, average per year .	105.0
1887–1893, inclusive, 7 crop years, average per year .	86.2

II. THE YIELD WITH COMPLETE CHEMICAL MANURE

	Baskets to the acre
1884–1891, inclusive, 8 years, average per year	164.2
1884–1893, inclusive, 10 years, average per year	183.4
1887–1891, inclusive, 5 crop years, average per year .	262.8
1887–1893, inclusive, 7 crop years, average per year .	262.0

III. THE YIELD WITH BARNYARD MANURE

	Baskets to the acre
1884–1891, inclusive, 8 years, average per year	169.5
1884–1893, inclusive, 10 years, average per year	194.7
1887–1891, inclusive, 5 crop years, average per year .	271.3
1887–1893, inclusive, 7 crop years, average per year .	276.8

IV. THE RELATIVE YIELD IN AN UNFAVORABLE SEASON

	Baskets to the acre
1889, unmanured	10.9
1889, fertilized	152.5
1889, manured	162.5

"The first point of importance and value observed is in reference to the number of crops that were secured. On the unmanured land, the crops secured after eight years were so small as to materially reduce the average for the whole period, while for the manured land the average for

the whole period was not only not reduced, but very materially increased; that is, the crops secured on these after the trees on the unmanured land had practically ceased to bear were greater proportionately than those secured previous to that time. This was true both for the fertilized and manured land.

"In the next place, it is shown that the yield was very materially increased by the use of manures, either in the form of artificial or natural supplies, and the differences in yield derived from these two forms are very slight, indicating that very much smaller amounts of actual plant-food in quick-acting forms were quite as useful as larger amounts of the less available forms in which the food exists in natural manure products.

"For the ten years, the fertilized plot received 250 pounds of nitrogen, 560 of phosphoric acid and 750 of potash, while the yard manure plot received — assuming the average composition of yard manure — 2000 pounds of nitrogen, 2000 of phosphoric acid and 1600 of potash; yet with eight times as much nitrogen, nearly four times as much phosphoric acid and more than twice as much potash, the yield was but 113 baskets greater, or an average of 11 baskets to the acre.

"In the third place, it is interesting to observe — and it is a point of great importance — the effect of an abundance of food in overcoming unfavorable weather or seasonal conditions. The year 1889 was extremely unfavorable, and the crop throughout the state was small. In this experiment the unmanured plot yielded at the rate of 10.9 baskets to the acre, while the manured and fertilized plots both showed a yield exceeding 150 baskets to the acre. The manure strengthened and stimulated the trees, and enabled them to successfully resist such conditions as were fatal to the crop on the unmanured land.

"This point is one that is seldom considered in calculating the advantages to be derived from proper manuring, though it is of extreme value, since the expenses of cultivation, trimming and interest on investment are quite as great in one case as in the other."

Methods of fertilizing.

The peach industry has so extended in the past few years that soils of natural high fertility possessing ideal conditions for peach-production have long ago been utilized. The peach crop is no longer a luxury in the farmers' homes, but a staple food commodity in all of the markets of the country. Many orchards are located on the poorer soils, and many more are being planted annually, and this is especially true of peaches which may be grown successfully on the lighter types of soils. In order that the health and vigor of the trees be maintained it is necessary to supply plant-food in abundance. At the same time the demand for natural manures, yard and stable manure, has increased, and with the advent of motor-drawn vehicles, the supply has decreased, leaving the use of commercial fertilizers the logical means of supplying the necessary food for the tree.

If commercial fertilizers are to be used efficiently, something must be known of the habits of the tree and of the kinds and amounts of plant-food required. Good, warm, naturally well-drained soils, even though they contain relatively small amounts of plant-food, are better adapted for peaches than for apples, because the former are shorter lived, grow relatively more rapidly and have a relatively greater power of acquiring food than the longer-lived trees. This statement brings out the character of the tree. Work done at the New Jersey Experiment Station, New

Brunswick, shows the kinds and amounts of plant-food that are needed in order to grow the tree and to make mature fruit. "It was shown in that experiment that an acre of peaches would require annually after coming to the period of bearing, and averaging 2000 baskets of peaches to the acre in ten years —

Nitrogen	71 lb.
Phosphoric acid	22 lb.
Potash	48 lb.

or an equivalent each year of nitrogen equal to 460 lb. of nitrate of soda, phosphoric acid equal to 150 lb. of acid phosphate and potash equal to 100 lb. of muriate of potash."

At about the same time experiments conducted in Germany showed the average quantities of nitrogen, phosphoric acid and potash, and lime removed by apples to be —

Nitrogen	71 lb.
Phosphoric acid	20 lb.
Potash	80 lb.
Lime	95 lb.

and for pears the quantities removed to the acre were:

Nitrogen	91 lb.
Phosphoric acid	18.5 lb.
Potash	71 lb.
Lime	120 lb.

The results confirm in a remarkable manner those obtained in this country for peaches, more particularly the large amounts of plant-food required annually in the growth of these crops. In the German experiments, the greater amounts of potash are in all probability due to the more liberal supply at the disposal of the German farmers. The amount of lime is likewise interesting and remarkable.

With these figures in mind, it is obvious that upon soils of poor chemical character, but possessing good physical condition, much larger amounts would be required than upon those soils which are well supplied in this respect, but whatever the soil, the tree will need additional food for proper growth, assuming, of course, that a part of the food necessary is derived from the stores of the soil. Assume also that in any case, and more particularly in the case of sandy soils, lime should be liberally used, because it is a well-known fact that the lime does have a very important influence in causing fruiting and encouraging that vigor and stockiness of wood growth that is so important.

The foregoing points very clearly to the need of artificial fertilization of peaches. No definite rules can be laid down as to the amounts to be applied, and no suggestions made, except that the moment a tree is hungry, that moment food should be supplied, and the evidence of hunger is so apparent in most orchards that much more fertilizer than is now used could be applied with very great profit. One should remember also that not only is the fertilizer necessary in order to feed the plant, but that an ample supply of food contributes to the power of the tree to resist insects and fungous attacks, to outgrow slight injuries, which would result in the absence of proper nourishment in very materially injuring the fruit prospects.

In order that the tree may be fed the moment it is hungry, an abundance of plant-food, especially the minerals, should be at its command. It is necessary to be more careful with the use of nitrogen. It has already been mentioned that it is well to have the soil in good condition before setting. It is not so necessary with peaches as with apples and pears, but it is a good practice to make an application of 300 to 500 pounds to the acre of a mixture

of equal parts of ground bone, acid phosphate and muriate of potash before the trees are planted, especially upon poor soils. For later years the following recommendations are made, based upon the results of experimental work conducted by the New Jersey Experiment Station:

For young trees — two to three years old, before coming into bearing:

150 lb. muriate of potash 300 lb. acid phosphate 100 lb. nitrate of soda	to the acre

For the first and second year of bearing:

150 lb. nitrate of soda 400 lb. acid phosphate 100–200 lb. muriate of potash	to the acre

During mature bearing:

200 lb. nitrate of soda 400 lb. acid phosphate 200 lb. muriate of potash	to the acre

These mixtures are by no means inviolable. Conditions modify their use. The character of the growth and yield of the trees will be a suitable guide to the application of fertilizers. If the yield is poor one year, the application of the next spring may be reduced 30 per cent, and also where leguminous cover-crops are grown as green-manures, the amount of nitrate of soda in the mixture may be reduced 25 per cent. The tree itself will show in its growth indications of either proper nourishment or lack of it which assist in the management of the orchard. (See Figs. 30 and 31, Plate XV.)

Whatever the fertilization, it should be remembered that the soil should be abundantly supplied with decaying

vegetable matter because this humus-forming material assists constantly by improving the physical character of the soil and the stores of plant-food, besides lending great aid in the conservation and better distribution of water, the one factor more than any other which controls size and quality of crop.

Many orchardists use much larger amounts of fertilizer than is here recommended, though if the suggestions concerning the method of use are carried out, the quantities named will be found sufficient to supply all the needs of maximum crops.

PLUMS, CHERRIES AND APRICOTS

The fertilizing of these fruits, when grown on the different classes of soils, need not differ materially from that recommended for peaches under the same conditions, though cherries, particularly, require in addition to the essential constituents, nitrogen, phosphoric acid and potash, a relatively greater supply of lime, and this substance should be applied in addition to the regular fertilization. Care should also be exercised in the application of nitrogen, in order to prevent a too great development of leaf and branch. Unless these trees show a decided need for nitrogen, a medium application of the second basic formula (p. 313) will furnish sufficient for their needs.

CITROUS FRUITS

These products — the oranges, lemons and the like — belong to a distinct class of fruits, and the experience already gained in their fertilization is such as to make applicable the suggestions concerning peaches, plums and apricots. On the lighter sandy soils of Florida, which are

naturally well adapted for oranges, growers have found potash to be a specially important element in manures. The nitrogen and phosphoric acid should be accompanied by a larger proportion of potash than is recommended for the stone fruits. Great care should be exercised in the use of nitrogen, though in the case of these semi-tropical crops the danger from immature growth, as in the case of fruits for the more northern climates, is not so marked.

SMALL-FRUITS

These crops do not differ from those already discussed in reference to their needs for liberal fertilization, yet because of their different character of growth, the method of fertilization should be somewhat different. They are, as a rule, crops which require a shorter preparatory season, and have a shorter period of bearing life. The strawberry, for example, does not advantageously bear more than two crops without resetting, whereas the blackberry and raspberry may range in life from four to eight years, and the gooseberry and currant are relatively long-lived, provided they are supplied with an abundance of food. In respect to their general character, they correspond more nearly with the vegetable crops than with the cereal grains, in that they possess a relatively higher market value and a lower fertility value than these, and the period of growth and development of the fruit is much shorter. Therefore, natural sources of plant-food may be largely ignored in their growth, and the more quickly available — particularly nitrogenous and phosphatic — materials supplied.

Strawberries.

In the case of the strawberry, the preparatory period of growth of the plant before bearing is but one year, and

the crop that may be obtained is largely dependent upon the strength and vigor of plant which has been acquired during this period. Hence, it is desirable that the soil in which the plants are set should be abundantly provided with the mineral elements, particularly with soluble and available phosphoric acid; hence an application of from 500 to 800 pounds to the acre of basic formula No. 1 (p. 313) is recommended. The nitrogen should also be in quickly available forms, and should be supplied in sufficient quantities at time of setting the plant to enable it to mature, and thus to withstand the rigors of winter. Hence, an additional application of 100 pounds of dried blood, or its equivalent in nitrate of soda, is advisable, particularly on soils not previously well enriched with organic nitrogenous matter. In the spring of the season during which the first crop is harvested, an application of a quick-acting fertilizer rich in nitrogen is desirable, since it not only provides for an early and strong growth of plant, but a better setting of fruit, if other conditions are favorable; and frequently, with a full setting, top-dressings with nitrate of soda are useful, in order to insure the full development of the crop. Many growers, therefore, who have supplied the soil liberally with minerals and nitrogen, both at time of setting the plants and in the following spring, make top-dressings of nitrate of soda (about 100 pounds to the acre), preferably after the plant has blossomed, in order to insure a sufficiency of this element. This should be applied at this time rather than later in the season, since later applications have a tendency to cause a soft growth of fruit, and thus injure shipping qualities.

Some growers find it a better practice to supply available nitrogen in the mixture used at the time of setting and in

spring rather than make partial applications of nitrate of soda; and others prefer to use nitrate of soda alone at the time of setting and supply the minerals as a top-dressing during the summer. If a complete fertilizer containing available nitrogen is to be used as above suggested, 400 to 600 pounds of the formula given on page 313 would give excellent results.

Raspberries and blackberries.

Raspberries and blackberries also require a soil well enriched with the mineral elements, which insure an abundant and strong growth of canes. The need for nitrogen, while apparent, is less marked than in the case of the strawberries, and the slower-acting forms serve a good purpose, provided they are not applied in too great quantities, so as to encourage a late growth of plant, which does not fully mature. The main object is to obtain strong, well-ripened canes, and this can be accomplished with the slowly available nitrogenous substances, provided an abundance of the minerals is present. An annual application in spring of 500 pounds to the acre of basic formula No. 2 (p. 313) will furnish sufficient food on soils of good character, though on lighter soils additional nitrogen should be supplied, preferably in forms not too active. The practice of applying quick-acting nitrogen early in the spring, after plants have blossomed, has been followed with great success, particularly upon the lighter soils, as it encourages a more complete development of fruit, though it should be used with caution, since the fruit canes of both the present year and those which provide the plant for the next year naturally grow in the same bed, and the young canes may not mature properly if too heavy applications of nitrogen are made.

Currants and gooseberries.

These are crops which, under average conditions, are seldom heavily fertilized, though fertilizing is usually followed with great profit. They are less likely to need nitrogen than the other crops mentioned, and a too heavy fertilization with this element has a tendency to encourage the development of mildew, the disease so common to these crops. In common with the other crops mentioned, they should be abundantly supplied with the minerals, phosphoric acid and potash, and the basic formula already recommended (p. 313) may be used in all cases with profit at the rate of 500 to 1000 pounds to the acre. The additional nitrogen needed may be provided by the slow-acting materials. Many growers find such waste products as wool and hair of great advantage in the growing of these crops.

Cranberries.

This crop is very peculiar in its habits of growth, and also in its choice of soils. It thrives upon muck soils and upon sand. Experiments conducted by the New Jersey Experiment Station show that the value of fertilization of cranberries depends quite as much upon the drainage and irrigation of a bog as it does upon the soil. When these conditions are satisfactory, liberal applications of minerals, particularly phosphoric acid, upon muck soils increase the growth of vine and the size and quantity of the berries. On such soils 400 pounds of acid phosphate and 100 pounds of muriate of potash may be applied.

Upon light, sandy soils, nitrogen is quite as important as phosphoric acid and potash, but it is necessary to exercise

great care in the application of nitrogen because it is likely to cause too great a growth of vine at the expense of fruiting. In general 150 pounds of nitrate of soda, 300 pounds of acid phosphate and 100 pounds of muriate of potash to the acre is sufficient where a uniform growth of vine is present. At all events, the fertilization of cranberries is of very recent origin and no definite rules can be laid down. It is an individual problem with each grower. The recommendations above are based upon work done by the New Jersey Experiment Station by the author. The results obtained by the Massachusetts Experiment Station under Cape Cod conditions seem to contradict the New Jersey results.

GRAPES

Grapes are more exhaustive as a crop than most of the fruit crops, largely because of the larger total crop harvested, and the special need is for phosphoric acid and potash. These elements may be supplied by the basic formula (p. 313), and very liberal dressings are recommended — from 1000 to 2000 pounds to the acre annually — after the bearing period begins. On light soils, an annual spring dressing of nitrate of soda, at the rate of 200 pounds to the acre, is also desirable, in order to encourage rapid and large early growth of leaf and vine, though this dressing may be omitted if the growth of clover as a green-manure is practicable. The latter, however, as when used in connection with the other fruits mentioned, should not be allowed to mature, but rather be plowed down early in the season.

The main point in the fertilizing of all fruits is to provide an abundance of the mineral elements, and to give

particular attention to fertilization with nitrogenous materials. It must be remembered that it is the fruit, not the wood, that constitutes the crop, and that all the energies should be directed toward the development of such a tree or vine as will best contribute toward this end.

CHAPTER XVII

FERTILIZERS FOR VARIOUS SPECIAL CROPS

In addition to the generally familiar crops already described, there are certain special ones, not distinct from the others because they are of less importance, but rather because they are only grown in certain localities.

COTTON

Among these special crops, cotton takes first rank, because it is one of the leading crops of the country, occupying wide areas, and exercising fully as great an influence upon our agricultural prosperity as any other of our American staples.

The climate suitable for the growing of cotton is confined to about one-quarter of the area of the country, and in this area it occupies a more important position than any other crop grown there.

In the earlier history of its cultivation, the methods employed were not such as to encourage the largest yield. In the first place, it was grown on the poorer soils rather than on the more fertile, and after it had been grown consecutively upon the same lands for a number of years, and thus rapidly exhausting them, the planter, instead of attempting to improve the lands, either by better methods of culture or by the use of manures, extended the areas under cultivation. After the civil

war, when it became still more necessary to change methods, fertilizers were looked to as the main reliance, rather than the improvement of the character of the soil, either by judicious rotation or by manuring. The results secured from the use of fertilizers at this time were so generally satisfactory that their large and indiscriminate use was encouraged, and this, without proper attempts at the improvement of the soil in other respects, hastened the time when such use did not give profitable returns. The very great importance of the crop to the agriculture of the leading cotton states, and the necessity of better methods of culture, were so fully appreciated that a scientific study of the crop was then entered upon, and the states largely interested planned, through the aid of their colleges and experiment stations, a wide series of experiments, which were directed toward the solution of the problems connected with the feeding of the plant. The results of these experiments have been fruitful of such valuable information as to warrant practical and specific suggestions which have a wide application, and which, if followed, will result in the improvement of the soil and in the economical increase in crop.

As already stated, the cotton crop is not an exhaustive one in one sense, though the methods of practice used in its growth have been wasteful, and thus have given rise to that belief. That is, a large crop of cotton does not remove from the soil a very considerable amount of the fertilizer constituents. The following amounts are contained in a crop yielding 300 pounds of lint to the acre:[1]

Nitrogen	46 lb.
Phosphoric acid	12 lb.
Potash	30 lb.

[1] Farmers' Bulletin, No. 14, Department of Agriculture.

Fertilizers for cotton.

In regard to its need for fertilizing, cotton may be classed with the cereals rather than with the crops already discussed; and like the cereals, its best growth is attained when properly introduced into a rotation with other crops, and the annual food supply arranged in such a manner as to contribute to the larger yield of the immediate crop, as well as to furnish an unused residue which will provide for an increase in the yield of the succeeding ones. Of the constituents, phosphoric acid seems to exercise a greater influence upon the growth and development of the cotton plant than any other element, notwithstanding the fact that smaller amounts are contained in it than of either nitrogen or potash. That is, it appears that the plant must have an abundance of available phosphoric acid at its command in order that the other constituents necessary for a full crop may be freely absorbed, though on the soils adapted for the crop, which naturally vary widely both in their general and special physical characteristics, but are poor in the fertility elements, both nitrogen and potash must be applied, in order that maximum crops may be obtained.

On the whole, therefore, though the "intensive" system is not generally practiced, fertilizers furnishing all of the constituents are superior to those which furnish but one or two; yet when proper rotations are practiced and leguminous crops are grown for the purpose of improving the physical character of the soil, as well as increasing its content of nitrogen, the percentage of this element introduced into the fertilizer may be very largely reduced.

The conclusions that have been arrived at by the

experiments conducted in the various states have been very fully set forth in various publications,[1] and the following statements drawn from these indicate what are believed to be the advantages derived from the right use of fertilizers, and the best methods to be observed:

"The cotton plant responds promptly, liberally and profitably to judicious fertilization. The maturation of the crop may be hastened, and the period of growth from germination to fruiting may be so shortened as to increase the climatic area in which it may be profitably grown. It should be assigned to a place in a rotation system. One of small grain, corn (with peas) and cotton, is well suited for the conditions prevailing in the cotton belt, and, as with other crops, the results derived from the use of fertilizers for this crop are much enhanced by the proper preparation of the soil. It pays to bring up the cotton lands by mechanical treatment, and especially by introducing organic matter. The renovating crops, especially the cowpea, are very profitably employed as adjuncts to the fertilization of the crop itself. On the majority of soils, too, it is advisable, and more generally proves profitable, to use a complete fertilizer, rather than one containing one or two of the constituents; and of the forms of nitrogen, organic (vegetable and animal) is best suited to the cotton, if one form alone be used, although nitrate of soda is probably nearly, if not quite, of equal value. The relative advantages of various proportions of the different forms have, however, not yet been fully determined; hence the use of a mixture of the best is a

[1] Farmers' Bulletins, Nos. 14 and 48, Department of Agriculture. Office of Experiment Stations, Bulletin No. 33, Department of Agriculture. Various bulletins issued by the Georgia, South Carolina and Louisiana Experiment Stations.

safe plan, the proportions to be determined by their relative cost. In the case of phosphoric acid, superphosphate is to be preferred to materials of an organic or mineral nature, which are not immediately available. Of the potash salts, no particular difference is observed in the use of the different forms. The form to be secured is to be based upon the price of the different forms."

Formulas for cotton fertilizers.

While the most judicious proportions of soluble phosphoric acid, of potash and of nitrogen in a complete fertilizer cannot be said to have been determined with entire accuracy, the carefully conducted experiments of both the Georgia and South Carolina stations indicate that for general use 1 part of nitrogen, 1 of potash and $2\frac{3}{4}$ or 3 of phosphoric acid indicate the best proportions. The amount of fertilizer that may be profitably used very naturally varies widely, though medium rather than very large dressings are recommended, not so much because the plant under good soil conditions could not appropriate and use to advantage large amounts, but because on the whole, soils used for cotton are peculiarly lacking in those qualities which enable the proper distribution and appropriation of the larger quantity. For those soils, then, the amounts per acre indicated by the Georgia Experiment Station are annually —

Nitrogen	20 lb.
Available phosphoric acid	70 lb.
Potash	20 lb.

The South Carolina Experiment Station recommends an acre application of —

Nitrogen	20 lb.
Available phosphoric acid	50 lb.
Potash	15 lb.

or, as suggested by the Georgia Experiment Station, perhaps a fertilizer containing —

Nitrogen	3%
Phosphoric acid (soluble)	9%
Potash	3%

applied at the rate of 700 pounds to the acre, would be approximately the best amounts to use under ordinary circumstances.

Method of application.

The fertilizer should be applied in the drill at the time of planting, and at the depth of not more than three inches, and well mixed with the soil. In most cases it is best to apply all of the fertilizer in one application rather than in fractional applications, though with lands in superior condition profitable applications may be made again at the second plowing. Owing to the nearness of the cotton belt to the supplies of superphosphate, and to the cheap supplies of cotton-seed meal, the only fertilizer necessary to import is potash. Hence it has become a practice in most sections for the planter to make his own formulas, using his own supplies of phosphoric acid and nitrogen; and home mixtures, made up of acid phosphate, cotton-seed meal and muriate of potash, or kainit, are largely used to supply the demands. The following formula is an example of a good mixture:

Acid phosphate	1200 lb.
Cotton-seed meal	600 lb.
Kainit	200 lb.

The formula containing —

Nitrogen	3%
Phosphoric acid	9%
Potash	3%

is also recommended, since an application of 700 pounds per acre will furnish the amounts and proportions of the elements indicated as the maximum by the Georgia station. This formula is also well suited for corn, if introduced into a rotation as previously suggested.

TOBACCO. (See Fig. 32, Plate XVI.)

Tobacco is another special crop grown only in certain localities, favored either by reason of climate or character of soil, or both. It is, however, a very important crop in this country, and one which requires very careful attention in reference to the amounts and kinds of fertilizers applied, because the fertilization exercises an influence upon both the yield and quality of the crop. It is an exhaustive crop, drawing heavily upon both nitrogen and potash. A crop yielding 1000 pounds of leaf to the acre will contain, in round numbers, 67 pounds of nitrogen, 9 of phosphoric acid and 85 of potash: amounts equivalent in nitrogen to over 400 pounds of nitrate of soda, of phosphoric acid equivalent to 75 pounds of acid phosphate, and of potash equivalent to 170 pounds of muriate of potash. It is a fact, too, that tobacco of the best quality, or that best suited for cigar wrappers, can be grown to advantage only on light, sandy soils, — those not naturally well supplied with the fertilizing constituents. Thus, if large crops are to be secured, the soil must receive liberal supplies of food from artificial sources.

PLATE XVI. FIG. 32. — Tobacco, Lancaster area, Pennsylvania.

The influence of fertilizers on the quality of the crop.

A point of great importance in the fertilizing of tobacco is the influence of the constituents applied on the marketable quality of the crop, as for certain purposes, especially for the manufacture of cigars and cigarettes, the tobacco must possess peculiar characteristics in order to bring the highest price in the market. In other words, in the growing of this crop, as is the case in many others, both the yield and quality must be taken into consideration, and frequently the latter point is of quite as much importance as the former, though a reasonable yield must be secured before the influence of quality is of practical significance. The quality of the leaf is believed to be influenced chiefly by the constituent potash, though many growers object to the use of various nitrogenous and phosphatic materials, believing that they, too, exercise a decidedly unfavorable influence upon the quality of the leaf. Careful experiments, however, do not justify many of the opinions of growers and dealers regarding the effect of the different materials upon the quality of wrapper tobacco.

The main points, therefore, in the fertilizing of tobacco are to see to it that a sufficient quantity of plant-food is applied in order to secure the largest possible yield consistent with quality, and second, to avoid the use of such constituents as are positively injurious.

The conclusions from Connecticut experiments.

Experiments in the application of fertilizers to tobacco have been carried out at the Connecticut Experiment Station with great care and skill for a number

of consecutive years.[1] They lead to the conclusion that "there is no 'best' tobacco fertilizer, or 'best' formula for all seasons, even on the same soil. A formula or a form of plant-food which in one season gives the leaf a somewhat better quality than any other may, perhaps the next year and on the same soil, prove inferior to others, for reasons which can only be surmised.

"Nevertheless, by comparing the effects of these fertilizers for a term of years, it appears that certain ones are, on the whole and generally speaking, more likely to impart a perfectly satisfactory quality to the leaf than certain others.

"It is doubtless true of tobacco, as of other crops, that the liberal but not greatly excessive supply of readily available plant-food yearly required to insure a paying crop may be given in a variety of forms with equally good results, on the average of one season with another, and that, indeed, occasional changes in the form of nitrogen and potash supplied may be a distinct advantage, avoiding always any considerable quantity of those things, as chlorin, and sulfuric or other free acids, which experience has shown may damage the leaf."

These conclusions in regard to the kind and quantity of fertilizing constituents required for the growing of tobacco of good quality confirm those arrived at by experiments elsewhere, and the suggestions made are sufficiently definite to guide in the use of fertilizers for this crop. In brief, therefore, the tobacco crop must be provided with an abundance of all of the fertilizer elements derived from readily available forms, and free from those constituents known to exercise an

[1] Connecticut Agr. Exp. Sta. Annual Report, 1897, Part IV, page 255.

unfavorable influence upon the quality of the product, in order that satisfactory yields of good quality may be secured.

Form of the constituents.

It has not been shown that one form of nitrogen is superior to another under all circumstances, or in other words, that one form of nitrogen — as, for example, ammonia, or nitrate, or any particular form of organic nitrogen, vegetable or animal — is superior to all others, but rather that any or all of the good forms may be used in a mixture, provided a sufficient abundance is present to insure a maximum yield, though not so large an amount in excess of the minerals as to encourage a rank, coarse growth. Phosphates have been neglected because the crop takes out very little, but recent tests indicate that moderate use of them gives a healthier crop, a somewhat larger crop and perhaps of somewhat better quality. The phosphoric acid should be in available forms, and if in these forms, must naturally be drawn largely from superphosphates. The potash should in all cases be drawn from sources free from chlorids. A fertilizer, therefore, which contains the nitrogen, either in good organic forms, as cotton-seed meal or blood, or a mixture of these organic forms with ammonia or nitrate in not too large amounts, which contains the phosphoric acid in a soluble form, and potash derived from products free from chlorids, — as from high-grade sulfate, or from a carbonate, or from cotton-hull ashes, if these are obtainable, — may be regarded as well adapted for the crop.

Amounts to apply.

An annual dressing which will furnish 100 pounds of nitrogen, 75 of phosphoric acid and 150 of potash to the

acre may be regarded as a minimum for soils of medium quality. On lighter soils heavier applications should be made, and on soils previously well enriched with the fertilizer constituents, the dressing may be somewhat less. It must be remembered, however, that it is not economical, from the standpoint of either yield or quality, to be too sparing in the application of fertilizers, because the plant requires large amounts of both nitrogen and potash, and because it is essential that the plant should have a reasonable excess of these at its command, in order to overcome as far as possible any unfavorable seasonal conditions that may occur.

In the Connecticut experiments already referred to, amounts greatly in excess of those suggested have been used with advantage, and the following formulas are cited as fair examples of what would be good fertilizers for an acre:

Cotton-seed meal	2000 lb.
Sulfate of potash	300 lb.
Precipitated or dissolved bone	200 lb.
Lime	300 lb.
Total	2800 lb.

or

Cotton-seed meal	1500 lb.
Fish	500 lb.
Double sulfate of potash	500 lb.
Acid phosphate	400 lb.
Lime	300 lb.
Total	3200 lb.

In Kentucky and Virginia, on soils naturally richer, smaller amounts have given quite as good results. It is likely, however, that upon the very light soils of certain of the states in which tobacco of high quality is grown, notably Florida, considerably increased amounts may be used with profit.

As sources of at least part of the nitrogen and potash in the southern states particularly, cotton-seed meal and cotton-hull ashes are recommended, because readily obtainable. These forms have been found to be good, and they may be obtained as cheaply as other forms as well as more conveniently.

SUGAR-BEETS

The purpose in the growth of sugar-beets is to obtain the largest total yield of sugar to the acre; and inasmuch as the sugar content of the beet, as well as its right growth and development, is very largely influenced by the character of the fertilization, this matter becomes of very considerable importance, in view of the promising development of the sugar-beet industry in this country. Thus far, information concerning the use of fertilizers is derived largely from the results obtained in other countries, where it has been a prominent crop, and where great attention has been paid to this factor in its production.

The demands of the crop for plant-food.

The sugar-beet draws heavily upon the soil for the nitrogen and potash constituents. A minimum yield of 10 tons of topped beets contains 44 pounds of nitrogen, 20 of phosphoric acid and 96 of potash. On medium, loamy soils, which by their character are well adapted for the growth of the sugar-beet, heavy fertilization with potash, however, has not been found to be desirable; while on light soils, which are also well adapted for the crop, liberal manuring with potash becomes absolutely necessary.

As in this crop, the object of the growth is to secure

not primarily beets, but sugar, and since the sugar formation is not perfected until the absorption of the necessary food from the soil has been in large part completed, any fertilization which promotes a too rapid or too long-continued growth has a tendency to reduce the percentage of sugar; and inasmuch as the maturation takes place largely in the months of early fall, the growth must be forced early in the season. That is, it is essential that a large and rapid leaf growth be made early, in order that the food from the air may be acquired. It has been demonstrated that for this early and rapid growth of the beet, phosphoric acid is one of the most essential constituents, which explains the need for phosphoric acid in larger proportion than is indicated by the composition of the beet. The crop requires a considerably greater supply of phosphoric acid at this stage of its growth than other farm crops which are quite as exhaustive, and it is also evident that in order that the crop may obtain the phosphoric acid at this period, it must be soluble and immediately available; hence the larger portion of this element applied should be derived from superphosphates. In the matter of fertilization with nitrogen, the object of the growth must also be kept in view. An application which would encourage steady and continuous growth, rather than an early and rapid growth, while contributing to a large yield, causes a reduction in the sugar content of the beet. Hence it is strongly urged by those who are in a position to give sound advice, that the early nitrogen fertilization should consist of the quickly available forms, nitrate or ammonia, and that the organic or slower-acting forms should not be applied in such excess as to encourage a late growth. Hence it is, that upon medium and light lands the use of commercial fertilizers has proved of greater

service in the growing of this crop than the exclusive use of yard manure, and in such quantities as to supply the entire needs of the plant. In the use of fertilizer, not only the total supply of the constituents, but their form, may be regulated to the needs under different conditions, thus permitting a full feeding of the plant, and at a time most suitable to accomplish the object in view,—advantages which are not possessed by the natural manures.

A fertilization which would meet the needs both in respect to quantity and kind of fertilizers may be as follows:

On good soils, the application of a fertilizer containing from 40 to 50 pounds of nitrogen, from 50 to 60 of phosphoric acid and from 40 to 50 of potash would be sufficient to meet the demands of the plant. The nitrogen supplied should be derived largely from nitrates or ammonia, or both, and the phosphoric acid from a superphosphate, while the potash may be derived from sulfate or muriate of potash. The former is preferable if applied during the spring preceding the planting of the beets. While it is frequently desirable, for convenience and economy of labor in applying, that the fertilizer should be mixed, in order to prevent any waste of soluble nitrogen, it should be applied in fractional dressings. For example, a mixture of 250 to 300 pounds of nitrate of soda (or the nitrogen may be derived partly from nitrate and partly from ammonia), 400 to 500 pounds superphosphate and 80 to 100 of muriate or high-grade sulfate of potash should be applied in two or three dressings. A part only should be applied previous to sowing, for both the nitrate and the potash salts have a depressing effect upon germination. They are preferably applied, say, one-third of the mixture as soon as the plants have come

up, another third immediately after or before the first cultivation, and the remainder immediately after or before the second cultivation. The application of the fertilizers in these forms and at the times indicated insures the rapid and early growth and development of the plant; and by reason of the solubility of the nitrates and ammonia salts, a late feeding of the plant with nitrogen is obviated.

On light or medium soils, the amount of plant-food should be increased by at least one-third, though fractional applications should be made as previously recommended. On soils rich in vegetable matter, a part of the nitrogen may be omitted, though the phosphoric acid should not be reduced.

The influence of previous deep cultivation of soil.

Another point to observe in the growing of beets for sugar — and it also has an immediate bearing upon fertilization — is the character of the previous cultivation. If the soils have not been deeply and well cultivated, so large a dressing as is here recommended would be likely to be deleterious, as with a shallow and poorly prepared soil plants would have less opportunity to penetrate deeply, and thus too great a growth above the surface of the ground would be encouraged, with a consequent lowering of sugar content as well as yield.

The best practice in this country will have to be developed by the experience of our own growers, although in the absence of such experience the recommendations here made may be relied upon. In many sections in which soils and climate are well adapted for the sugar-beet, the needs as yet are quite as much for improved methods of cultivation as for added fertility. They have not been exhausted of their essential fertility.

SUGAR-CANE

Another special crop, confined largely to one state, Louisiana, is sugar-cane, and perhaps no other one crop has in this country received such careful study in reference to its needs for plant-food. The Sugar Experiment Station of that state has for twelve years conducted a series of systematic experiments designed to answer the questions as to what the needs are for nitrogen, phosphoric acid and potash; and the results of this work thus far secured furnish suggestions in reference to fertilization, which will, if carefully followed, undoubtedly result in the production of better crops than are grown under present systems. Fertilizers are clearly needed, and their right use is a profitable practice, though, as stated by Doctor Stubbs, "many ascribe the failure from their use to the worthlessness of the fertilizer, when it should be ascribed to some defection of the soil, rendering it incapable of appropriating the applied fertilizer."

The chief conclusions in reference to fertilizers for sugar-cane in Louisiana, so clearly set forth by Doctor Stubbs in this report,[1] are here summarized, as it is believed that the underlying principles are applicable elsewhere, though naturally their use must be modified to suit individual cases.

The needs of the plant as indicated by the Louisiana experiments.

"An examination of the cane plant shows that a crop of 30 tons will remove, in round numbers, 102 pounds of nitrogen, 45 of phosphoric acid and 65 of potash. It is, therefore, a relatively exhaustive crop, and unless the

[1] "Sugar-cane," Vol. I, Sugar Experiment Station, Audubon Park, New Orleans, La.

physical conditions are perfect, even good soils should receive considerable dressings of the constituents, if the fertility is to be maintained.

"The results secured thus far in the experiments referred to demonstrate that the soil needs nitrogen and phosphoric acid particularly, in order to grow cane successfully, while thus far, no results of any character, either in the increased sugar content or tonnage per acre, have been visible from the use of any form of potash upon the alluvial lands of the lower Mississippi. Several forms of potash, notably the carbonate, and ashes of cotton-seed hulls, have rather decreased the yield of cane and injured the physical qualities of the soil by causing it to 'run together.'

"In reference to the form and amount of nitrogen, it has been shown that sulfate of ammonia gives slightly better results than any other form, though its higher cost gives no advantage over those costing less, while cotton-seed meal comes next, followed by dried blood and nitrate of soda. In reference to the amount of nitrogen to be applied, it is shown that not less than 24 pounds nor more than 48 pounds to the acre should be applied. Naturally, different soils and different kinds of cane would vary in their requirements for this element, and the amount needed would also be influenced by the method of growing the crop: whether upon 'succession' land — that is, upon soils upon which a crop of stubble cane has just been taken off, and which has been in cane for a number of years without the intervention of a leguminous crop between to restore the nitrogen — or whether upon pea-vine land, upon which the plant cane is grown the first year, stubble cane the second, and corn and cowpeas the third year. This system of rotation, which introduces a

leguminous crop into it, not only improves the physical quality of the soil, but enables a considerable accumulation of nitrogen, frequently over one hundred pounds per acre. The pea-vine lands, put in plant cane on account of their excellent physical condition, not only yield up readily the nitrogen stored up by the pea, but can also assimilate larger quantities of plant-food applied as fertilizer. Hence, such cane usually makes large crops. Since nitrogen is the chief ingredient taken from the soil by a crop of cane, it follows that with each successive crop of cane grown on the land without the interjection of the leguminous nitrogen there arises an increased demand for nitrogen. Hence, stubble cane requires larger quantities than plant cane, and the older the stubble, the larger its requirements for this element."

In reference to phosphoric acid, the results so far indicate positively the value of this element in fertilizers for sugar-cane on these soils, but the demand for this ingredient is small in comparison to that for nitrogen, 36 pounds to the acre being ample for the crop. The results further show that the soluble forms of phosphoric acid are preferred. Inasmuch as the leguminous crop does not add to the store of phosphoric acid in the soil, it is equally needed by both plant and stubble cane.

While potash has not been shown to be needed on the land upon which the experiments were conducted, because of the abundance of potash contained in the soil, after continuous cropping of these and on lighter soils this element should be included in the fertilizer.

The application of fertilizers.

For plant cane, a small quantity of readily available fertilizer directly under and near the cane is highly

beneficial, as it provides food also for the sucker, which, with food at hand, is greatly aided in developing a healthy sucker, and thus the entire plant is given a vigorous send-off in youth. It is necessary, to give a good start to a young plant, to withhold manures until a stand is secured, though when cane is planted during the fall and winter, as it is in Louisiana, the danger of loss by leaching must be reckoned upon, and the exact amounts to be applied at that time regulated by the judgment of the planter. Usually the more perfect the incorporation of a manure in the soil, the better the results to be expected, but in this case it should be deposited in a drill and well mixed with the soil. In the spring, after the cane is closely off-barred, the fertilizer, if not applied at planting, should be scattered on both sides of the plant from the center of the row to the off-barred furrow. Thus, in reversing the furrow, the manure is covered, and subsequent cultivation will mix the latter with the soil. If the cane has received the first application at planting, the second one should be given in May, on both sides of the row. The stubble cane should not be fertilized very long before each sprout has sent out its own rootlets, since prior to this no good could be accomplished, and there would be a waste of manure.

HOPS

Little interest has been taken in the matter of fertilizers for hops because they are grown largely upon very rich soils in the West where little fertilizer is used, while in the East the interest in hop-culture is decreasing. Farm manure is at present the standard fertilizer, but many growers are now beginning to use commercial fertilizers. In the fertilizing of hops, the quality of the

product is an important consideration, and an excess of available nitrogen which is liable to cause a too rank growth and green hops of an undesirable quality should be avoided. Hence, 600 to 800 pounds of the following mixture would supply sufficient plant-food in the right forms:

Nitrate of soda	50 lb.
Dried blood	100 lb.
Tankage	200 lb.
Acid phosphate	450 lb.
Muriate of potash	200 lb.

FLAX

Flax is a peculiar crop to feed because it has a very fine tap root and few root-hairs, and because it makes its growth in a relatively short period of time, forty or fifty days, it is often termed a dainty feeder. Few investigations have been made to determine the best kinds and amounts of plant-food to use. The practice of successful growers seems to show that liberal applications of manure or the use of green-manure for two or more seasons supplemented with nitrate of soda as needed gives satisfactory results. In the absence of farm manure or green-manure, 300 to 400 pounds of a mixture made as follows should supply sufficient amounts of the elements, though nitrate of soda may still be used, as needed, as a top-dressing:

Nitrate of soda	250 lb.
Dried blood	100 lb.
Acid phosphate	500 lb.
Muriate of potash	150 lb.

MISCELLANEOUS CROPS

Other crops of importance for which the need of fertilizers is frequently apparent include sorghum, buck-

wheat, peanuts, roses and herbaceous plants, lawns, grasses and plant-house vegetables. These are, of course, similar to those already described, since their best development requires that they shall be well supplied with the fertilizing constituents, nitrogen, phosphoric acid and potash, though their special needs in this respect have not been so fully investigated as the other crops dealt with in this chapter. The discussion of their requirements is, therefore, necessarily brief, and the suggestions made are of a general rather than a special character, though they may serve as a safe guide.

Sorghum.

Sorghum is grown both for forage and for sugar, and its fertilization should be discussed from these two standpoints. If grown for forage, the fertilization should be more liberal and of a different character than if for sugar, as the object is the largest yield of succulent food rather than the highest yield of sugar, and the yield of sugar is not always consistent with the highest yield of cane. For forage, therefore, the fertilizer recommended for maize forage (p. 262) is well adapted for sorghum on soils in a good state of fertility, though since the plant is very slow to start, its early growth is stimulated if a larger amount of readily available nitrogen is used than is desirable for corn, particularly on soils of medium fertility, and which have not been previously well fertilized. If grown for sugar, too much nitrogen must be avoided, since an excess of this element in the fertilizer causes an imperfect ripening, and consequently a higher percentage of non-crystallizable sugar in the cane; though if quickly available forms are used, as nitrate, ammonia or dried blood, which may be absorbed by the plant

early in the season, a larger amount may be applied with safety than if the poorer forms are used. Of the three constituents, potash in the form of muriate seems to be the one exercising the greatest influence upon the yield of sugar, hence it should always be introduced in considerable amounts in fertilizers for sorghum.[1] A fertilizer furnishing 20 pounds of nitrogen, 35 of phosphoric acid and 60 of potash to the acre will meet the needs on average soils.

Buckwheat.

Buckwheat is frequently grown upon the poorer soils of the farm. It is a crop well adapted to mountain lands, and as a preparatory crop in the breaking of new lands. It has not been carefully studied in reference to its needs for plant-food, though phosphoric acid seems to be the constituent more particularly required than the others. Its need of nitrogen is marked, yet because its entire growth and development are made during the months of July and August, when conditions are most favorable for soil activities, heavy nitrogenous fertilization is not to be recommended, except when grown on very light soils, or those deficient in vegetable matter. The moderate use of fertilizers rich in minerals, and which contain nitrogen in quickly available forms, result favorably, not only in increasing the yield, but assist materially in maturing the crop, a matter of great importance. A fertilization with 25 pounds to the acre each of phosphoric acid and potash and 10 of nitrogen may be regarded as a good one for soils of medium character.

[1] Report for 1886, New Jersey Agricultural Experiment Station.

Peanut.

The peanut is a leguminous plant, and, like others of this family, is not specifically benefited by nitrogen, but responds readily to liberal dressings of phosphoric acid and potash. The fertilization suggested for green-manure crops, namely, a mixture of three parts acid phosphate and one part muriate of potash, or equal parts of acid phosphate and kainit, may be used for this crop with great advantage. The applications, if frequently made, need not exceed 300 to 400 pounds to the acre. Like other leguminous crops, it is specifically benefited by lime, medium dressings of which (20 bushels to the acre) should be made at least once in four years. In the districts in which this crop is successfully grown, lime marls are frequently obtainable at slight expense, and may be used with great advantage.

Roses and other flowering plants.

In the growing of roses and other herbaceous plants, of which the flowers constitute the crop, great care is usually taken in the preparation of the soil, and natural soils are seldom used. Notwithstanding the richness of the prepared soils, the crops are benefited by the addition of commercial fertilizers, particularly those phosphatic in their nature. Ground bone is especially useful, since it furnishes both nitrogen and phosphoric acid in slowly available forms, and usually sufficient nitrogen to meet the needs of the plant, as excessive quantities of this element cause a too vigorous and rank growth of foliage, which is not accompanied by profuse flowering. A good mixture for the prepared soils, therefore, may consist of four parts of ground bone and one part of muriate of potash, which

may be applied at the rate of four pounds to the square rod of area, and well worked into the soil previous to setting the plants. The after fertilization may contain a larger portion of the soluble phosphoric acid, which is more readily distributed. The need for nitrogen is indicated by a yellow, rather than a bright green, color in the foliage. Nitrogen may be supplied by light dressings ($\frac{1}{2}$ to 1 pound to the square rod) of the active forms of this element, preferably nitrate of soda, because of its ready distribution. In the preparation of soils for these plants in the house, the mixture may be applied at the rate of 2 pounds for every 100 square feet of surface, the after application to consist of the more soluble forms as recommended for the hardy plants. An even mixture of nitrate of soda and acid phosphate may be used at the rate of one pound for every 100 square feet of surface once in two weeks, if the plants do not show vigorous growth.

Lawn grasses.

The fertilization of lawns is also important in a sense, because proper fertilizing obviates the necessity of the home manures, which, although excellent as sources of the constituents, are frequently offensive. The use of manure also involves considerable labor, both in the application and the consequent removal of the coarse part in the spring, besides resulting in the introduction of weed seeds. In the preparation of the soil for a lawn, it must be supplied with an abundance of all of the necessary fertilizer ingredients previous to seeding, and of these phosphoric acid and nitrogen are especially important. Too great an excess of potash encourages the development of the clovers rather than the grasses. This preparatory

fertilizer may contain the more slowly available forms of nitrogen and phosphoric acid. Ground bone is an excellent source of these elements, and a mixture of five parts of ground bone and one of muriate of potash makes an excellent dressing. This may be applied at the rate of five pounds to the square rod, and thoroughly worked into the soil. The after-fertilization may consist chiefly of nitrogen, preferably as a nitrate, since its ready solubility permits of its free penetration into the lower layers, which encourages a deeper root system, and thus greater resistance to drought.

The top-dressings with nitrate of soda should consist of light fractional dressings, rather than of large amounts at one time. One-half pound to the square rod, twice or thrice during the season, — the first as soon as the grass is well started in the spring, and preferably immediately preceding a rain, — will, if the land has been previously prepared well, be sufficient. To facilitate the distribution of the nitrate, as well as to supply a sufficient abundance of phosphoric acid, it may be mixed with equal parts of ground bone.

Forcing-house crops.

A rich garden loam, to which a considerable proportion of stable manure — one-third to one-half the bulk — has been added, is the usual type of soils for such crops as tomatoes, lettuce, radishes and cucumbers under glass. The addition of fertilizers to these is seldom advisable. It has been demonstrated, however, that such mixtures are not essential, and that the crops may be profitably and successfully grown in mediums which contain no plant-food,[1] if supplied with an abundance in

[1] Connecticut State Experiment Station Reports for 1895, 1896 and 1897.

available forms from artificial sources. In the absence of good manure, which is the chief expense, a reasonably fertile loamy soil may be used for filling the beds, in which at the time of filling may be mixed, for each 100 square feet of surface, one-half pound of nitrate of soda, one pound of acid phosphate, one pound of ground bone and one-half pound of muriate of potash. This application will be sufficient to supply the needs of the plants for food until growth is well started, after which they should be fertilized at least once each week with one-quarter of a pound of nitrate of soda for every 100 square feet of surface area, and with the mineral fertilizers at the rate of one pound of acid phosphate and one-half pound of muriate of potash every two weeks. These may be applied in solution, or evenly distributed over the surface of the soil, and worked in before watering. The amounts to apply should always be governed by the judgment of the grower. There is less danger from the application of too much, if properly used, than is commonly supposed.

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